JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLVI, NO. 1. 78TH YEAR. JULY, 1903

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THE FRANKLIN INSTITUTE.

Stated Meeting, held November 19, 1902.

Acetylene Stored and Transported in Safety.

BY JOHN S. SEYMOUR,
Formerly United States Commissioner of Patents.

Acetylene gas furnishes a brilliant flame which possesses great lighting power. Since it is about seventeen times as luminous as commercial city gas, and under low pressures is not more dangerous in manipulation, it might probably be used in all commercial gas plants were it not that the waste from leakage would be prohibitive. To light with acetylene, therefore, commercially speaking, calls for a generator of the gas on the spot, or else its transportation from a central station in steel tanks under pressure.

But acetylene under pressure is dangerous, and its use is prohibited alike by common prudence and by the rules of the underwriters.

The safe transportation and storage of acetylene in tanks of special equipment is the subject of the present discourse.

The method of storing acetylene in small bulk was discovered by Claude and Hess, French inventors, who ascertained that 1 volume of acetone, at the temperature of 15° Centigrade, at atmospheric pressure, dissolves 25 volumes of acetylene, and under 12 atmospheres 300 volumes, increasing nearly in proportion to the pressure. They communicated their discovery to the French Academy of Sciences (*Compt. Rend.*, 124, 626) in 1897.

One volume of water dissolves 1 volume of acetylene, turpentine dissolves 2 volumes, amyl alcohol 3·5, chloroform 4, acetic acid 6, alcohol 6, and paraffin 26. Water at 0° Centigrade and 1 atmosphere dissolves of nitrogen 0·02, of oxygen 0·041 volume, carbonic acid 1·79, sulphuretted hydrogen 4·37, sulphurous acid 79·79 volumes, and ammonia 1046·63. Alcohol dissolves more; for example, of carbonic acid, 4·33, whereas water dissolves but 1·79 volumes. For the same gas, the same liquid and the same temperature, the weight of gas absorbed is proportional to the pressure.

Claude and Hess proceeded with their experiments and found that the solubility of acetylene in acetone increases with extraordinary rapidity with the fall of temperature, especially as the point of solidification of the acetylene is approached. At minus 80° Centigrade, at ordinary atmospheric pressure, 1 volume of acetone dissolves more than 2,000 volumes of acetylene, while the solution occupies four to five times the volume of the original acetone. Lewes recites this at page 96.

Acetone, being one of the di-methyl ketones C_3H_6O or $(CH_3)_2CO$, may be derived from secondary propyl alcohol (C_3H_8O) and is a mobile liquid procured on a large scale from the aqueous liquid obtained in the dry distillation of wood, by the destructive distillation of acetates and various organic compounds. It is often prepared by the dry distillation of barium acetate at a moderate heat.

Unlike aldehydes, the ketones do not polymerize, but their most remarkable property is an inclination to condense, that is, two or more molecules join, with the elimination of water, forming a new compound. The boiling point of acetone is 56·3 C. = 133·34 F., and it has a biting

taste. It is used in making chloroform and as a solvent for fats, camphor and resins.

Acetone is miscible in all proportions with water, alcohol, ether and many ethereal salts, and can be separated from its aqueous solution by the addition of calcium chloride.

Why acetone dissolves this large quantity of acetylene is a question related to the sum of all the qualities of the two substances. Acetylene, C_2H_2, that is, HC:CH, is produced (1) when an electric arc is formed between carbon points in hydrogen; (2) further by passing the vapor of many carbon compounds, alcohol, ether, methane, ethylene, through red-hot tubes; (3) by the reaction of water upon calcium carbide. It has a molecular weight of 26, a density of 13, specific gravity, according to Bethelot, of ·92, theoretical 89·85. One liter weighs 1·165 grams at 0° C. and 760 millimeters. Its specific heat is 1·26, its heat of combustion from 310,000 to 317,000 calories.

Acetylene condenses at plus 1° C. at a pressure of 48 atmospheres. Edmund Davy found that it required 2½ volumes of oxygen, or approximately 12½ volumes of air, to complete the combustion of 1 volume of acetylene, and that 2 volumes of carbon dioxide and 1 of water vapor were produced. Berthelot states the composition of acetylene as carbon 92·3, hydrogen 7·7, total 100, the ratio of carbon to hydrogen being as 12 to 1.

It is, of all the hydrocarbons, the richest in carbon, and is the only one which contains its own volume of hydrogen without concentration. Thus, C_2H_2 represents 2 volumes as a whole and the H_2 alone represents 2 volumes.

The emphatic illuminating power of acetylene results from its high proportion of carbon, which in suspense in the flame gives it a marvelous brilliancy of great whiteness, in comparison with which the incandescent electric lamp appears dull and yellow. It also results from the high temperature of its combustion. It must be burned in a thin flame under a pressure rather greater than that of illuminating gas, about 4·25 inches of water pressure, in order to secure complete combustion, for otherwise the flame be-

comes smoky by the very reason of its great richness in carbon.

Donner says, page 169, that methane gives 3·5 carcel hours of light per cubic meter of the gas burned; that the normal gas of the city of Paris gives 9·6, of the city of London 11·5, while of acetylene a cubic meter gives 168 carcel hours of light per cubic meter, sixteen times that of the light of Paris, or, as Vieille found in his photometric tests, twenty times the light of illuminating gas in Paris.

Acetylene evolves little heat, and one can, without inconvenience, pass the hand near the flame. For the same quantity of light emitted, the heat evolved by the combustion of acetylene little exceeds that coming from the incandescent lamp. Acetylene contains proportionately much more glowing carbon in the flame and much less hydrogen, not glowing but of great calorific power, than oil gas. Moreover, in proportion to luminous intensity the quantity of acetylene burned is much less than the quantity of oil gas.

The researches of Messrs. Bertholet and Vieille have shown us that, at atmospheric pressure or under the tension of a few atmospheres, acetylene gas may be handled with safety. Under these conditions it is no more dangerous than illuminating gas.

The theoretical heat of combustion of a cubic meter of acetylene, which weighs 1·2 kilograms, taking the average of five trials, is 14,029. A cubic meter of illuminating gas has a heat of combustion averaging 5,500 calories. That of acetylene is almost two and one-half times higher; but Perrodil adds: "Nevertheless, I say at once that for equal light acetylene develops much less heat."

As we shall see hereafter, unit light by acetylene is produced at a mean expense for one hour of 7 liters when the combustion is well regulated, but 7 liters will give in burning 98 calories. The same light with oil gas is obtained since the discovery of the incandescent mantle with 25 liters, which makes 125 calories. If we place the hand above a little flame of acetylene it seems that it does not give any heat and that only comes from the very small delivery of the tip.

Acetylene is the starting point of all organic chemistry. Beginning with pure carbon, we could succeed in forming and obtaining by a series of reactions an infinite number of organic compounds. By well-known reactions we may derive from acetylene, oxalic acid $C_2H_2O_4$, alcohol C_2H_6O, acetic acid, wood spirits or methylic acid, and the whole fatty series.

We may also form the aromatic series. By heating acetylene to a dull red heat in a curved bell jar placed over mercury, we can produce benzine by the union of three molecules of acetylene C_6H_6, and these in turn may be transformed into nitro-benzine $C_6H_5NO_2$, and into aniline $C_6H_5NH_2$, and thus we may obtain the series of aniline colors.

By heating acetylene still more, we may obtain the condensation of four molecules, or styrolene C_8H_8, which with benzine gives anthracine $C_{14}H_{20}$, and anthracine oxidized gives alizarine $C_{14}H_8O_4$, a beautiful red color identical with that which natural madder produces.

Acetylene may be united directly with the unsaturated hydrocarbons. Perrodil, p. 54.

Nascent hydrogen or hydrogen in the presence of platinum black is united to acetylene to give ethylene.

If in a vase filled with water saturated with chlorine we let a few fragments of calcium carbide fall, we see acetylene evolved which burns in contact with the chlorine. P. 55.

Alcohol was always obtained by the distillation of fermented liquors, wine, beer, cider, etc., which springs from the action of ferments or micro-organisms upon sugared liquors, and which transform, we know not how, certain sugars into carbonic acid and alcohol.

Then follows the process of deriving alcohol from acetylene, but it is costly. P. 58. Sugar may be formed from acetylene. Pp. 58–59.

COMBUSTION OF ACETYLENE.

Acetylene burns in contact with air with a brilliant but smoky flame, giving water and carbonic acid. Two volumes of acetylene will give, with 5 volumes of oxygen, 1 volume

of vapor of water and 2 volumes of carbonic acid. They evolve at the same time a quantity of heat equal to 318·1 calories, as follows:

Two molecules of carbon give in burning 24 × 8·8, equal to 193·9 calories. Two molecules of hydrogen give 2 × 34·5, equal 69 calories, making a total of 262·9 calories.

But in burning, the acetylene restores the calories which it dissolved for its formation, to wit, 55 calories, which represents the heat of formation which was absorbed in starting from the elements of amorphous carbon.

Returning to the solution of acetylene in acetone, it is interesting to see the operation taking place.

A glass siphon-bottle containing 820 milliliters was partly filled with 250 milliliters of acetone, filling the bottle about one-third full—the height was marked on the glass. A standard pressure gage was attached to the glass jar and a similar gage to a force pump connected with a reservoir charged with acetylene. Acetylene was pumped into the jar with the valve open in order to let the air pass off. The valve in the jar was then closed, the pumping continued until 3 atmospheres had been pumped in, the bottle being shaken all the time. It was then blown off until acetylene bubbled up from all parts of the liquid, whereupon the pumping was resumed. In twenty minutes the pressure gage showed 10 atmospheres. The acetone rose in the bottle 12 millimeters and the bottle became slightly warm to the touch. Again blowing off the bottle until bubbles came up from the acetone so as to dispose of the air, the manometer went down to 8 atmospheres, and then on closing the valve to the jar the manometer rose to 9·33 atmospheres. The jar with the manometer attached was then connected to a gas meter and 10 burners and a large Bunsen burner, the latter consuming 2 feet an hour, and all were lighted. In ten minutes after the jar was connected to the gas meter and the valve opened, more than 33 liters had passed through the meter. The pressure fell to zero, and all without shaking the jar. On shaking the jar the manometer rose ½ of 1 atmosphere, and at the end of five minutes of shaking 4 more liters came out, making in all 33 liters of

acetylene that had been dissolved in ¼ of a liter of acetone at 9·33 atmospheres.

Subtracting from 820 milliliters the 250 milliliters of acetone, we have 570 milliliters as the contents of the jar above the acetone before it was expanded by the acetylene, which, being multiplied by 9·33, gives 5,320 milliliters of compressed gas above the surface of the acetone. Remembering that more than 33 liters of acetylene had passed through the meters and the burners in ten minutes, and subtracting the more than 5 liters from that leaves 28 liters that were dissolved in a few minutes in ¼ of a liter of acetone, or at the rate of 112 volumes at 9·33 atmospheres, or at the rate of 120 volumes at 10 atmospheres. This is about half the absorbent power of the acetone, but the difference is due to the short contact of the gas with its solvent and to the heat due to the compression of the gas and to the chemical action implied by the solution.

The solubility of gases and liquids in water has not been exhaustively examined, and the vast majority of determinations are of but little value owing to neglect of conditions to ensure accurate results; but it is certain that the diminution of volume undergone by the more soluble gases is extremely great and equal to that produced by pressures which are far beyond practical application. Thus Thorpe's Dictionary of Applied Chemistry gives it that a saturated solution of ammonia gas in water contains an amount of gas condensed to such a volume as would, if effected by pressure alone, require over 500 atmospheres, or about 3·5 tons per square inch. Of course, the gas would be liquefied long before this pressure would be reached.

The application of this principle to the storage and transportation of acetylene gas is at a single step to realize all the advantages of impossible pressures in reducing bulk and by the use of only moderate pressures of from 10 to 15 atmospheres.

The gas comes forth readily from the liquid when the pressure is released, and can be utilized by the aid of a reducing valve in the ordinary applications of light. Vieille, of the Council of Public Health and Safety in the Depart-

ment of the Seine, found and published officially in 1898 that on condition of not exceeding the degree of saturation corresponding to pressures of 10 atmospheres at the ordinary temperature of 15° C. about, the solution of acetylene in acetone constituted an inert liquid, capable of withdrawing the acetylene which it absorbed from all known means of excitation; that is to say, that the liquid neither detonates by shock nor by a fulminate priming.

Much was anticipated from this invention alone, and steel receptacles were made with a diaphragm furnished with a reducing valve at the orifice, on one side of which was to be the acetone and on the other acetylene at about 4·3 inches of water pressure. But the dangers of liquid expansion are encountered on one side, and without the diaphragm the compressed acetylene gas above the liquid remains explosive; yet it is a satisfaction to know that the explosion of this gaseous mass provoked artificially is not propagated to the liquid. In the upper part of the apparatus without a diaphragm, therefore, the same dangers would be present as would be found in a cylinder containing compressed acetylene alone. The fundamental discovery, therefore, of Claude and Hess thereby enormously increasing the capacity of a receptacle by partly filling it with acetone, required to be supplemented by another which would recognize and take care of the difficulty which I have just mentioned; and accordingly, Edmond Fouché, of Paris, equipped a receptacle containing acetone and acetylene with a porous substance, brick for example, of special make, of 80 per cent. porosity, and pierced with holes of about 1 millimeter in diameter, to facilitate the diffusion of the gas.

We have, therefore, the interior of the receptacle converted into interspace, minute communicating cells connected by small perforations, the walls of which are moistened with the contained acetone. This enormous surface of the acetone film gives a better contact with the acetylene as it is pumped in, and greatly facilitates the absorption of the gas. Other substances may be employed in the place of the brick; mineral wool, pumice stone, ceramic materials and carbon are all available. A composition

formed of cement and charcoal has been found very light, having a density of 0·3 and a porosity of 0·80, but it is applicable to compressed acetylene without acetone, the liquid being decomposed little by little by the chalk. We have found in this country that asbestos made in disks like the one now shown, encrusted with an application of liquid glass for stability, is most advantageous on account of its lightness, the crust not interfering unfavorably with the absorption. These porous substances have the property of eliminating all danger of accidental explosion from the the tanks, and of localizing the explosion if one be produced intentionally in such a cylinder.

I do not deal with the theory of this simple but effectual safety device, but the part taken by the porous substance in this case has been spoken of as analogous to that which infusorial earth plays in the case of dynamite. To me it seems more analogous to the principle employed by Sir Humphry Davy in the safety lamp, who found that flame would not pass through iron wire gauze of twenty-eight threads to the inch. Edmund Davy discovered acetylene in 1836, describing some of its more important properties in a communication to the British Association of that year. He found even at that early day that distilled water absorbed about its own volume of this gas; that it was evolved unaltered by heating, and adds:

"From the brilliancy with which the new gas burns in contact with the atmosphere, it is, in the opinion of the author, admirably adapted for the purposes of artificial light if it can be produced at a cheap rate."

The apparatus is extremely simple, and altogether consists of a tank of any usual form such as is used on every car lighted with either compressed city gas or compressed air enriched with gasoline vapor, as in the Frost carbureter system or in the Pintsch system. These cylinders are, in process of making, completely packed with asbestos disks or with porous brick of 80 per cent. porosity, and are then riveted together, unless made with one flanged head, and are then ready for use.

The cylinder that I now exhibit to you, shown in the

accompanying cut, *Fig. 1*, is in size 6 inches by 30 inches, and accordingly has a capacity of about ·49 of 1 cubic foot, or a little less than ½ of 1 cubic foot. It is made of mild steel $\frac{1}{16}$ inch thick, is tested to 500 pounds pressure, and is computed to withstand more than 1,500 pounds pressure to the square inch. We employ a pressure of only 240 pounds, or 16 atmospheres.

In practice, to get the greatest capacity, about 43 per cent. of the mathematical volume of the cylinder should be occupied with acetone, the liquid which dissolves the acetylene gas, which, saturating the asbestos or bricks, takes the form of a film of liquid lining the walls of the cells of the bricks. A ready means of introducing the acetone is to exhaust the air and then connect the inlet with the acetone and allow it to be drawn in. If now the acetylene be pumped into the cylinder, it is taken up by the acetone in the same manner as if the acetylene were pumped into the body of the liquid and allowed to bubble up through it. When the acetylene is pumped in at a moderate rate—and a half hour is taken to charge a large cylinder sufficient for a railway car—the acetylene dissolves in the acetone as fast as it is pumped in. If there is need of charging the cylinder more rapidly, it may be charged to a pressure of 15 atmospheres, from which it subsides in a short time to 10 atmospheres.

But the capacity of a tank for acetylene when thus equipped is 100-fold the mathematical contents. A standard tank on a railway car is 10 feet 4 inches in length and 19½ inches internal diameter, containing about 21·5 cubic feet. By Boyle's law, if illuminating gas or air or acetylene be pumped into this tank without this equipment of brick and acetone, or any filling, at 10 atmospheres, 10 fold the contents will be contained; that is, 215 cubic feet of gas at 150 pounds pressure; but with the asbestos and the acetone in the proportions named, 10-fold this amount may be pumped in at the same pressure, or 2,150 cubic feet of acetylene; and if double this pressure is employed, 4,300 cubic feet may be stored therein at but 300 pounds pressure, and when the pressure is relieved from the tanks the acetylene comes forth unaffected by the acetone, of which there is but a

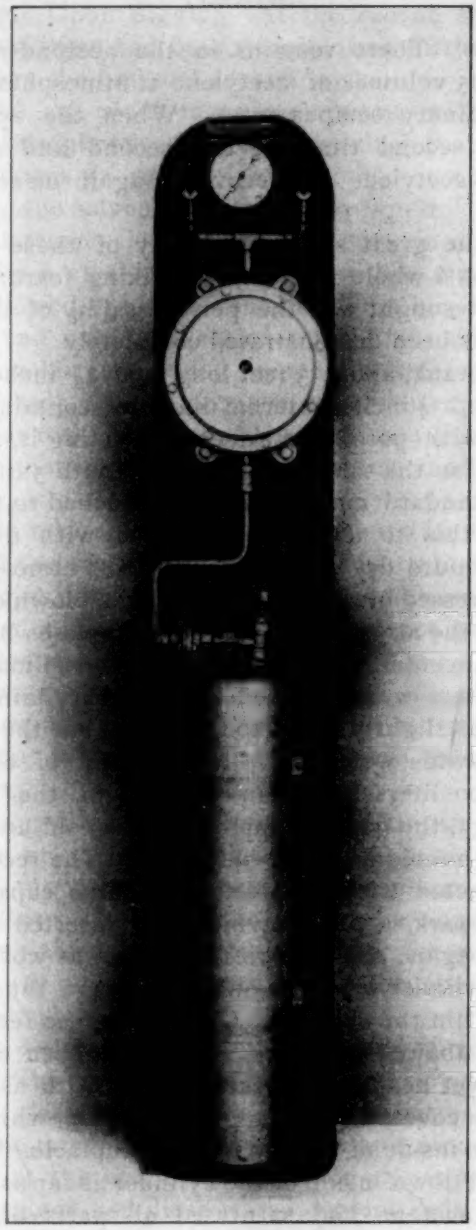

FIG. 1.—Exhibition cylinder, 6 x 30 inches, about one-half of one cubic foot, holding 80 cubic feet of acetylene at 16 atmospheres.

trifling loss. There remains in the acetone an original charge of 25 volumes of acetylene at atmospheric pressure and at ordinary temperatures. When the apparatus is charged a second time all the second and subsequent charges of acetylene are recovered again on relieving the pressure.

While the great storing capacity of these inventions combined as a whole is always a striking feature, the principal object sought was the perfect safety of the process, and this has been demonstrated completely.

A steel tank, about 3 feet long and 4½ inches external diameter and 3½ inches internal diameter, containing 7 liters, was filled with porous bricks exactly fitting it, which after being fitted in the tank were saturated with 3 liters of acetone. A standard manometer was attached to the service-pipe and this to a pump connected with a gas-holder containing pure dry acetylene. When 5 atmospheres had been compressed into the cylinder, it was blown off, in order to displace the air within it, which compresses but does not dissolve in acetone. Starting again with the manometer at zero, 200 liters were pumped in in twenty minutes. The cylinder was slightly warm to the touch, but the pump and other apparatus were cold. At the end of eighty-seven minutes 700 liters had been pumped in, the manometer stood at 12·5, the general apparatus was cold and the cylinder almost as cold as at the beginning. The receptacle was then connected with an electric machine capable of producing a spark, a plug having been inserted before the pumping began; the electric machine was worked rapidly while the cylinder was in an outside passage, thus producing a spark within the cylinder. On opening the receptacle the first brick, about 1·75 inches, which had been cut away to pass the rivet heads and packed around with asbestos, was found to be covered on the top with carbon, which had also covered the inside of the cap of the receptacle. The carbon had worked down inside of the cylinder as far as the second brick, the acetone had saturated all parts of these two bricks, which were then taken out. Some of the carbon had filled the space between the first and second bricks, but

not entirely. Upon digging out the second brick it was apparent that there had been no explosion further than the space between the first and second bricks.

M. Fouché has made many experiments with pressures up to 35 atmospheres, each one showing that with this simple apparatus we render inexplosible, not only the free gas, but also the solvent and absorbing liquid.

A similar receptacle charged with acetone and gas was connected by a steel pipe provided with a stop-cock and acetylene allowed to blow off sufficiently to expel all the air. The outer end was then sealed up and placed over two large Bunsen burners, which heated the steel pipe nearly to a white heat. On taking the apparatus apart, it was apparent that the acetylene which had been dissociated in the pipe had not communicated its explosion to the chamber itself.

Vieille, in making his own experiments for the city of Paris, found, and stated officially in his report, that this apparatus had for its effect to transform to a condition of security these recipients filled with a porous substance and charged with dissolved acetylene.

The apparatus has been raised to the boiling point and retained there, the experiment occupying more than three hours, without raising the pressure to more than forty-two atmospheres.

A gratifying circumstance and one contributing to safety is that when an electric spark was made in a steel cup at 200 pounds, the manometer being put on showed only 135 pounds pressure. In another instance, where a much larger tank was subjected to the sparking test, the manometer, standing at 150 pounds pressure before the spark, immediately after stood at 125.

Similarly, Lewes records that on heating pure acetylene in a curved tube over mercury to a temperature sufficient to soften hard glass, the volume of the gas decreases and at the same time tarry products make their appearance. In one experiment at the end of a half hour 97 per cent. of the original acetylene had disappeared, leaving only 3 per cent. untouched, whilst almost all the hydrogen of the acetylene

was found in the liquid and solid products of the reaction. When higher and more prolonged temperatures were employed, the acetylene being passed through a red-hot tube was almost entirely decomposed into carbon which was deposited and hydrogen which was set free, always with decrease of volume.

In the details of one of the experiments recorded by Lewes, the volume of the acetylene before heating was 309 cubic centimeters, and after heating 174·2, or a little more than one-half the volume.

The fact that acetylene contains only its own proper volume of hydrogen, that of all the hydrocarbons it contains the least hydrogen, that hydrogen is occluded in the carbon that is formed by dissociation, that the liquid and solid products that result from the contact of acetylene with red-hot iron all contain more hydrogen than the acetylene contains, and that polymerization of part of the acetylene takes place, all bear upon the interesting fact that acetylene when in contact with red hot iron decreases in volume.

The pressure of acetylene dissolved in acetone confined in a tank decreases one-half for a decrease of 54° F.; but, as might be expected of a tank equipped with this large body of asbestos, the response of the tank is exceedingly sluggish to changes of temperature.

Thus, in a test made for Dr. Charles B. Dudley, of the Pennsylvania Railroad, a small tank 57 inches in length by 4·75 inches in diameter, charged with acetylene at 3 atmospheres, was maintained for three days at about 60° of temperature F. The day before the test it was put into an upright zinc cylinder out-of-doors in very cold weather, the thermometer at seven o'clock in the morning of that day and the day of the test registering 12° above zero.

On arriving for the test, the tank having been standing in the zinc cylinder for a day, the manometer showed $2\frac{1}{8}$ atmospheres with a temperature of about 14° F. The space between the tank and the enclosing cylinder was then filled with a freezing mixture consisting of 10 parts of ice, 5 of salt and 2 of nitrate of ammonia, producing an intense cold registering 14° below zero. In a half hour the pressure

descended to 2 atmospheres. In three hours the pressure was 1 atmosphere, and the temperature near the top about 12° below zero. It was thought to be much colder lower down in the tank. The gas was turned on to three burners, the tank still standing in the freezing mixture, but the gas flowed freely. Ten feet of gas were thus taken from the cylinder in about one hour and a quarter.

The next day the tank was raised to a temperature of 60°, but it took two hours to do it. Ten feet of gas had come out the day before, and 20·5 feet the second day, and although the manometer showed no pressure, the gas came forth when the valves were taken off freely, showing a thick smoky flame 18 inches long with considerable pressure.

Another tank was charged to 10 atmospheres at zero, and then raised to 80° without the release of any gas. The maximum pressure was 350 pounds, but it required from 3.15 in the afternoon to 4.21 to do this in the case of a tank about 3 inches in diameter.

Car No. 234, on the Lackawanna R. R., equipped with four lamps, each with 3½-foot burners, and one in the toilet-room, thirteen lights in all, ran continuously from March 14 to April 16, 1902, about eight hours a night, and the tank was then about half full, showing 75 pounds pressure. In all, the car ran, according to official records, 360 hours without recharging; or at the rate of four hours a day, which is the common service of a car, it ran ninety days without recharging. (*Fig. 2.*)

The yacht "Oneida" ran all summer lighted from one tank 7 feet long and 19½ inches in diameter without recharging.

The portability of this system might be illustrated by a tank-car having four tanks with an aggregate capacity of 1,500 cubic feet. This would carry at 10 atmospheres 150,000 cubic feet of acetylene, conveying gas for 300,000 hours of light with one flame, or sufficient to maintain twenty lights 15,000 hours, or at four hours a day sufficient to maintain twenty lights for 3,750 days, or over ten years. This would be sufficient to light 120 cars for a month, or to

FIG. 2.—D., L. & W. car, lighted with acetylene in safety tanks.

light a freight warehouse and switching station employing 100 lights nine hours a night for a year without recharging.

Signal towers and the adjoining switches, perhaps twenty in number, furnish a special lighting problem. Tanks charged with acetylene dissolved in acetone can be transported throughout a railroad system by freight, and the empty tanks exchanged for the full ones, with no greater trouble than would be required to send direct the calcium carbide to the separate stations for generating the gas on the spot. All the acetylene that is produced by 100 pounds of calcium carbide can be transported in a 5-foot tank.

This invention has a highly respectable origin, and it has passed its experimental stage. It has been for more than two years last past in use in Paris on the cars of the Chemin de Fer de Funiculaire de Belleville, and it has been pronounced a perfect success. It has to some extent been used in construction work by the city of Paris itself. It is used in more than 300 houses and factories in and around Paris. It has been authorized by the insurance companies of Paris. It has been authorized and permitted by the eminent engineer Vieille, having charge of explosives and illumination for the city of Paris, and his official permit is issued for its use within the city.

In England it comes under the Explosives Act of 1875, a statute enacted before acetylene came into commercial importance, but which is sufficiently broad to cover it. Under the provisions of that Act, orders of council are issued from time to time, and one was issued on the 26th day of November, 1897, under Section 104, which declared that acetylene, when liquefied or when subject to a certain degree of compression, should be deemed an explosive within the meaning of the Act.

But on the 10th day of April of the year 1901, the Honorable Charles T. Ritchie, one of His Majesty's principal Secretaries of State, having examined this invention, certified that it had been shown to his satisfaction that acetylene, when compressed into these porous bricks, with or without the acetone, was not possessed of explosive properties, and he thereupon issued his order under the Act in question that it

should not be deemed to be an explosive within the meaning of that Act, provided certain conditions were observed, such as that the cylinder should be tested and marked, and that an inspector should have access to the cylinders.

Acetylene will not supplant city gas, nor electricity, nor oil, nor candles; but for special applications, particularly for railway cars, even electric cars, small railway stations, lighthouses, piers, country houses, buoys, small towns, temporary installations for fairs and conventions, boats, automobiles, railroad signals, lantern projections and photography, it is well adapted.

If, as Huxley says, out of the contemplation of pumps grew the discussion about Nature's abhorrence of a vacuum, whence it was discovered that Nature does not abhor a vacuum, but that air has weight, and *that* paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe; in short, bringing in the theory of universal gravitation and endless force, no sincere and patient study of a problem in the applied sciences is likely to be without enlightenment in the study of pure science.

The *commercial handling* of acetylene opens up vistas of discovery even in the recondite problems of life. We cannot doubt that in the progress of mind working upon fixed and verifiable data as its material such discoveries will be made. If to others it seems improbable, it was Aristotle who observed:

"Perhaps one might call this very thing a probability, that many improbable things will happen to men."

CURIE EXPERIMENTS WITH RADIUM.

Professor Curie has announced to the French Academy of Sciences that radium possesses the extraordinary property of continuously emitting heat without combustion, without chemical change of any kind, and without any change in its molecular structure. Radium, he states, maintains its own temperature at a point 1·5° C. above the surrounding atmosphere. In other words, the quantity of heat evolved is such that a pure radium salt will melt more than its own weight of ice every hour, and half a pound of a salt of radium will evolve in one hour heat equal to that generated by burning one-third of a cubic foot of hydrogen gas. Despite this constant activity, the salt apparently remains just as potent as it was at the beginning.

THE FRANKLIN INSTITUTE.

Stated Meeting, held April 15, 1903.

The School City.

By Wilson L. Gill,
General Supervisor of Moral and Civic Training, Public Schools of Cuba under the American Administration.

Object of Public Instruction.—The greatest aim and object of public education is to cultivate in the individuals to be educated a good conscience, and to secure for them a wise and resolute self-government and the desire and ability to co-operate for the common good; or, in other words, a good character. Sharpening the wits and storing the memory with facts, the apparent object of schools, colleges and universities, is, in reality, but a minor matter, and will easily and necessarily follow the attainment of the chief end of education. A practical method which may be used in a wholesale way in all schools, for students of all ages, which makes it possible and easy for teachers to lead their pupils to cultivate good conscience, to govern themselves wisely and to co-operate for the general good, will do for the cause of morality, education and human welfare, what the steam-engine and electric apparatus have done for the cause of manufacturers and human comfort. The School City method of popular government has proved itself to be fully adequate to this great purpose. This large claim is not rashly or unadvisedly made. It is not claimed, however, that this method can take the place of other needed progress in public instruction, made necessary by the social, political and industrial evolution which has accompanied the general introduction of machinery and the immense emigration from the farms to the cities, all of which have a direct bearing on the moral and civic conditions, and, consequently, call for notice in this place. The changed conditions demand, for the public thrift and the public safety, that children be trained in productive industry, and that intelli-

gent attention shall be given to making a healthful division of the children's time among bookwork, productive industry, recreation and rest, and to the proper housing and feeding of the people. Let it be noted that by productive industry is not meant that kind of manual training in which a child is engaged only two or three hours a week, and in which he uses up material furnished out of the public funds and does not give a visible and commercially valuable and adequate return.

Teaching the precepts of morality and the doctrine of one's relation to his fellows and to his country, is as old as literature. Enterprising and true teachers have always sought for ways to put such teachings into practice, and they have been successful as teachers in proportion to their success in this matter. A well-developed method of practical character-building and training in morality and in performing the duties and exercising the rights of citizenship in a thoroughly systematic, wholesale and successful way is new. Cuba is the first country in the world to require such training in the public schools. Every country should require it as a matter of public policy, and the highest legislative power in the State ought to give authority to it. There are many school teachers and officers who are bright enough to see the importance of training the children in citizenship and to form good characters, and there are many who are sufficiently unselfish and self-sacrificing to perform the labor of thinking about and installing what is to them a new method in their schools. Such teachers should be encouraged to begin the work without waiting to be compelled by law. Even such enterprising ones need the encouragement and help of constant supervision by a competent and legally authorized specialist in moral and civic training. Such special supervision is at least as important as State supervision of any branch now taught in the schools. This is necessary for many reasons, a notable one being that many teachers who have had no experience in the use of the method and do not fully understand the principles involved, think it would redound to their credit if they should change the plan and thus make it appear to be wholly or at least

in part their own. Such ones generally fail in accomplishing the object of the School City, and the whole plan is abandoned, unjustly discrediting the movement. Some of these same teachers would have succeeded had they been under competent supervision.

There are school teachers and officers who will not take the trouble to introduce this method. Whether or not the latter are in the vast majority may not be of much import-

Police Court in a Havana School City.

ance. That there are any such, is sufficient reason for looking to the higher powers for favorable decision in this matter.

A Question for Statesmen.—Whether the children of a nation shall be trained as subjects of a monarchy, as is being done ordinarily throughout the world, or as self-respecting, co-operating citizens of a republic, is a question that de-

mands the attention of broad-minded statesmen, whose insight is sufficiently penetrating and whose outlook is far-reaching enough to enable them to discover a vast peril to the great republic at the present time, whose judgment is good enough to enable them to recognize the remedy when it is placed before them, and who have enough back-bone to act promptly and effectively in this matter. They should put it beyond the choice of all who might hinder. They should lay down the law that the schools of a republic shall train its people while children as citizens, not as subjects, and that they shall make the developing of good character in the children the first aim and a specific practical part of the daily work of the schools.

Facts and Philosophy.—In the United States, the greatest and most successful of all republics, the one great failure in the government is the municipality, and this is a sore spot that threatens death to the republic. It is worth while to analyze the situation, with a view to seeing the principal causes for the weakness in American municipal government.

The most glaring defect is that a great mass of the educated people do not go to the primaries, and they neglect their municipal duties. That leaves the effective political voting power in the hands of those who are comparatively uneducated. They in turn are organized and manipulated by men who make a business of municipal politics, not always, but generally, for the money they can get from the public treasury, and, by means of blackmail, from private persons and establishments, and especially from those engaged in forbidden or restricted practices and business.

Lost Liberty and Death.—"Eternal vigilance is the price of liberty," and the educated people have not paid the price. Among the consequences are insufficient results from the expenditure of public funds, more disease and a higher death-rate than there should be. The people have lost a part of their liberty, if, because of the inability or dishonesty of the public servants, they must labor additional hours to pay their taxes, and quite as much so if they lose life because of bad drainage, dirty streets, impure water, bad

food or other evils which should be prevented by the government.

Schools and Colleges are to Blame.—As this state of affairs is charged to the account of educated people, let us take a closer look. We see practically the following: The uneducated men, who can be easily handled by the machinery of the bosses, all vote; most of those who have had but little schooling vote; less of those who have had much schooling vote; a college and university education is almost a certain guarantee that a man will not attend the primaries or perform his other municipal duties. This seems to throw the blame on the schools, colleges and universities. They teach right principles. The fault does not seem to be in the books. The fault is in the school management. From the primary school till the man graduates from the university he is made to feel and to know that he has simply to obey, and nothing further to do with the government of himself and his fellows, and that he is a tattle-tale and sneak if he brings a wrong-doer to justice, and is mean and dishonorable if, when called upon by the authorities to testify, he does not so shape his testimony as to clear the offender.

Anarchy Fostered.—Under this pressure, secret opposition and disloyalty to constituted authority is constantly fostered. Many pupils regard their pleasure and interest as opposed to those of their teachers, who are apt to be thought of as spies and in some cases as enemies, instead of friends and guides.

Old-fashioned school government is monarchy, in which the teacher endeavors to rule by means of his conscience and arbitrary authority, and the political results are as we see them in the municipalities of the United States.

The Remedy.—The recognition of the cause of the evil is almost a declaration of the only remedy, which is to systematically train the individual to wisely cultivate his own conscience and be governed by it, rather than by that of the teacher; to co-operate with his fellows for the common good, rather than for mischief; to form the habits of law and order, rather than those of anarchy. In other words, the remedy for the apathy of educated men, in reference to

their municipal duties, which is in effect anarchy, not of the lowest, but possibly the most dangerous type, is to train them while young to think and act to form the habits of citizens, instead of, as at the present, training them in the schools and colleges as subjects of monarchy.

Plan of School City.—The plan of the School City is to organize the children of each school, under a charter given by the higher authorities, as citizens of a municipality. These citizens elect a city council, who, in one phase of the plan, in turn elect a mayor, judge and other administrative and judicial officers. The mayor appoints his cabinet and subordinates, and has power to remove them at will. Nomination by petition, proportional representation and the initiative and referendum enable the whole body of citizens to express and enforce its will at any time, either with or independent of its representatives. Elections, for several reasons, occur frequently—once in ten weeks—and experience has shown that it is desirable to make the term of the police officers short. In most primary schools every citizen not elected or appointed to some other office is a candidate for a place on the police force, for which a high ideal of gentility and kindness is set.

I suggest the following code of laws, leaving the children free to accept, change or reject them and to make additional laws as circumstances require. They invariably accept them without change, and generally with much enthusiasm. The whole code is given to show how short and comprehensive it is.

SCHOOL CITY LAWS.

CHAPTER I.—THE GENERAL CITY LAW.

Do to others as you would wish them to do to you. This is the natural law, without which no popular government can succeed, and it is the general law of this School City, to which all other laws and regulations must conform.

CHAPTER II.—THINGS PROHIBITED.

ARTICLE 1. Do not to others that which you would not wish them to do to you.

Order.

ART. 2. Anything which disturbs the order in halls, class-rooms, or in any place within the jurisdiction of the School City is prohibited.

ART. 3. Anything which is profane, rude or intentionally unkind or impolite is prohibited.

Cleanliness.

ART. 4. Anything which detracts from the neat and orderly appearance in our School City is prohibited.

Health.

ART. 5. Anything which detracts from the healthful condition of our School City is prohibited.

Public and Private Property.

ART. 6. Anything which mars or destroys property in our School City is prohibited.

CHAPTER III.—DUTIES.

ARTICLE 1. Every citizen is in duty bound to call the attention of the authorities to any violation of the laws of this School City.

CHAPTER IV.—PUNISHMENTS.

ARTICLE 1. Any citizen violating any law of this School City shall be subject to punishment not less than a reprimand and not greater than a withdrawal of the rights of citizenship.

ART. 2. Every punishment must be approved by the principal of the school before it is carried into execution, and then promptly put in effect.

CHAPTER V.—OFFICERS.

ARTICLE 1. The police commissioner, with the consent of the mayor, shall appoint one chief of police for the school, and one captain of police and four policemen for each room. Appointments, before going into effect, must be approved by the City Council.

CHAPTER VI.—TERMS OF OFFICE.

ARTICLE 1. The term of office of all officers, unless otherwise provided, shall be until the next general election and until their successors are appointed or elected.

ART. 2. Captains of police shall serve two weeks, and policemen one week, unless sooner removed for cause by the commissioner of police.

Good Results.—Many instances of fine moral results are reported from the different schools. Of course, the results are not uniform, as the School City is not an automatic machine out of which all must come in exactly the same shape. It is a method, and its degree of success depends upon the interest and skill of the principal and teachers who use it.

Almost without exception, when a troublesome boy accepts the responsibility of an office in the School City, he instantly puts off his ugly old character and assumes one of glad obedience and respect for authority and others' rights, and at once begins to help in all that is right, instead of to hinder, as was his habit. If, then, the teacher under-

stands the method and is true to it, he will be friendly to the boy, consult and encourage him, sympathize with him and help him to maintain his enthusiasm, and the boy is saved permanently. Women teachers, with correct intuitions and hearts full of sympathy, if they understand the simple method, will seldom fail to make the work of regeneration permanent. Men or women who study and treat a boy as they would a trilobite, a noxious weed or poisonous snake, will almost surely fail to give the necessary aid to maintain the boy's enthusiasm and, of course, he will very soon, if not at once, begin to relapse into his former ugliness. The condition of the School City is an almost exact index of the character and condition of the head of the school and of the teachers.

The limits of this article will not admit of the introduction of official reports from American and native officers in Cuba, and unofficial reports of teachers in American schools, but they are numerous and favorable and many may be found in the library of the Franklin Institute.

Experience emphasizes the fact that best results demand good printed suggestions and helps for the teachers and children, and intelligent and authoritative supervision.

Monarchy and Democracy in Great Britain and the United States.—While the growth of the spirit of democracy has gone on for centuries in Great Britain, till to-day England is in name a monarchy, but in fact a great, free, democratic republic; in America, the vestiges of monarchy not wiped out by the Revolutionary War have gone on developing, till in some of our cities and States we have the name and machinery of a democratic republic, but in reality the spirit and the actual domination of monarchy.

The "bosses" or "leaders" are not to blame for this condition. The conditions have produced the "bosses," who are our real rulers as much as if we called them "kings" or "czars." Except by some sort of revolt against the present order of things in our municipal and State government, the only way in which a public-spirited man can render political service in those cities and States where boss rule has been established, is by making himself the boss or sub-boss or

entering the service of the existing uncrowned king, or else by helping to abolish the educational method and conditions which have prevented the educated men, while children, from forming the character and habits which are necessary to an independent, unselfish and faithful citizenship; and to establish such a method and condition in the schools as will aid the young people to build the character and establish the habits of ideal citizenship, successful steps have been taken both in the United States and Great Britain to estab-

Meeting of City Council in a Havana School City.

lish the School City for this purpose; but the movement is young in both countries and needs the support of every lover of his race to whom the knowledge of it may come.

Two Bosses.—Within a short time I have come in close contact with two political bosses. One is a highly educated, refined American gentleman, who derives his wealth from his private commercial enterprise. The sincerity and depth of his interest in educational matters and the general welfare and happiness of his fellow-countrymen is evidenced by the fact that his daughter, with no financial necessity, is an en-

thusiastic kindergartener, and he is proud of it; and though he sees that faithful, intelligent, tactful training in citizenship in all the public schools would mean the ultimate doom of bossism, he is ready to give his hearty support and co-operation for the general introduction of the School City. In a true democracy, it is such men that the people delight to trust and to honor. The other boss I saw and heard angrily denounce, with profane and vile language, a lady official, and taunt her as being a college graduate, because she raised her voice against impure methods in the appointment of teachers. This was in the presence of nearly a dozen of her official colleagues, all men, stalwart in body, but not one dared a word in protest against his insults to womanhood, education and the spirit of democratic republicanism. All were ashamed of the outrage, but they were in his power, and probably felt that they were helpless to oppose him. The object of this allusion to the two bosses is neither to condemn nor defend this development of monarchy in our midst. If the people want a monarchy under the name of boss government, by all means let them have it; but I am acting on the presumption that they do not want the spirit and conditions of monarchy in city and State affairs, any more than they do in national government. My object is to call attention to the fact that there are two kinds of bosses, and that some may be true gentlemen and patriotic, who are serving the welfare of their neighbors as best they can under existing conditions, and that they will gladly co-operate to establish in the municipalities a government more directly in the hands of the people, just as soon as the educated and best elements of the people are willing and prepared to habitually defend their rights and perform their duties as citizens.

Industrial, Moral and Civic Evolution.—When our Republic was young, the mass of her people lived on farms. Boys and girls went to school only two or three months in the year. For the rest of the time they labored with their parents in the fields and at the spinning-wheel and loom, always under moral, religious, industrial and civic influence and training. The hoe and spade of the Colonies have given

way to the steam-driven machines on the vast prairies; the spinning wheel and hand-loom to immense cotton and woolen mills; the country forge to stupendous rolling-mills, furnaces, foundries and forges. By such means the children of to-day are separated during work hours from their parents. The public schools, which consume these released hours and years in training the intellect and cramming the memory, make no systematic, intelligent endeavor to furnish that kind of character-training which our ancestors received from their parents. The War of the Revolution failed to wipe out that vestige of monarchy which lurked in the government of the little country school. That was too insignificant to be thought of, for in those days the American citizens' character was built in the open country, under the influence of their parents, the heroes of the Revolution. Now, American character is developed in great swarming buildings, under the weight of a heavy, crowded, intellectual curriculum, and that vestige of monarchy which was left in the school has grown, with the increasing months of the school year, to large proportions and is wielded by masters, who themselves have been trained as subjects, not as free men.

An Appeal.—Thus, the public schools and colleges, boasted bulwarks of our liberties, have unwittingly, but ceaselessly, nursed the spirit of monarchy, and through childhood and youth subjected our whole people to it, to that extent, that when they reach the age of manhood they do not go to the primaries and municipal polls, and thus they fail to enter into their heritage of citizenship. This is what has made government by the bosses possible. Fortunately, some of the municipal bosses, maybe many of them, are so patriotic that they would gladly see political power restored to an intelligent, active, faithful citizenship, and I hereby appeal to all American patriots and friends of a government of the people, for the people, and by the people, to join in this movement to provide that every child who enters a school-house shall be treated while there as a free man, and be confirmed in the character and habits of a free-born, faithful and patriotic American citizen, not only ready to die, if neces-

sary, for his native land, but what may be more difficult and quite as important, actually living for his country, patiently and fearlessly defending his rights and faithfully performing all his public duties.

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DEVELOPMENT OF THE GAS ENGINE.

Of late years the size of gas engines has much increased. Many makers are now building machines of 2,500 horse-power, and are ready to double this efficiency. The development of large gas engines is closely connected with the evolution of the fuel-gas processes, and it is noteworthy that the first gas engines in England above 400 horse-power were operated with producer gas, while many of the large gas engines in Europe have been built for use with blast furnace gas. In August, 1902, two English firms had under construction over fifty gas engines varying in size from 200 to 1,000 horse-power. A classified list of engines made or making shows 327 such, with an aggregate horse-power of 182,000, or about 560 horse-power per machine. The last volume of the United States census reports 18,500 combustion engines in the country, with a total capacity of 165,000 horse-power, or only about 9 horse-power on the average. This state of things is not likely to last long. One American firm has already sold over 40,000 horse-power of large engines, most of them of 2,000 and several of 1,000 horse-power. Another has recently built two 4,000 horse-power gas compressors and a number of 1,000 horse-power gas engines. The gas engines of the large sizes are extensively used for generating electric light and power, but there is a decided tendency to employ the smaller sizes direct as motors. Cheap fuel-gas processes will bring the gas engine to replace the electric motor for very many purposes, and we may look for development along these lines in the near future.

Dr. Robert H. Thurston, of Cornell University, says that two controlling tendencies mark the improvement in the efficiency for commercial purposes of every product of the engineer's labor; their resultant varies as the one or the other is in the ascendant. These are increasing costs with increasing efficiencies, and advancing expenditures with diminishing gain. As the outgo for increments of efficiency and economy continues, the gain by increased

efficiency is partly, or wholly, or more than wholly, compensated by the simultaneous increment of cost. With the crude apparatus of the earlier stages of uneconomical and incomplete industrial systems, there usually exist great opportunities for improvement by refinement of the apparatus and by systematizing the industry at, often necessarily, increased cost in the form of invested capital. Later, the possibility of further improvement lessens, and the costs to secure any given gain increase, until it ultimately becomes a fact that more must be paid for a given gain than it is worth, and the net outgo on the improved apparatus or system becomes, interest and sinking fund included, more than that on a less perfected machine or system. What may be called a "golden mean" is thus always found at that stage at which the cost of additional economies will exceed the necessary cost of securing them, and where the result of securing them is loss rather than gain. The resultant of the two tendencies takes a direction which thus tends toward the unprofitable, and a limit may thus always be expected to be found, beyond which further refinement is financially undesirable.—*Cassier's Magazine.*

NOTES ON NICKEL-STEELS.

M. Guillaume, assistant director of the International Bureau of Weights and Measures, has been making for several years a special study of nickel-steels. He has found in the series of alloys of iron and nickel a curious anomaly, of which one of the characteristics is a considerable falling off in expansion as compared with that which the ordinary law of mixtures should give. He has succeeded, according to Henri de Parville, in the *Journal des Debats*, with the assistance of the Société de Commentry Fourchambault, in obtaining alloys which contract when heated, a little after the manner of india-rubber. It is a curious result from which many important applications can be drawn. For example, there can be obtained alloys with so little expansion that it can scarcely be measured by the most delicate processes. A nickel-steel wire has been made which had an expansion of only 0·4 millimeter in a length of 1 kilometer, between 0° and 20° C. (0·0253 inch in a mile, between 32° and 68° F.).

The value of the new alloy for the compensation of chronometric apparatus and the measure of geodetic bases can be understood. In metrology the determination of variations in the length of the rods forms one of the great difficulties among the very difficult operations of geodesy.

M. Guillaume has also studied the changes which time produces in the alloys. The stability of the alloys is wholly sufficient for geodetic purposes and for the construction of compensated clocks. The Swiss manufacturers are already making compensators on which temperature has almost no effect. These nickel-steels contain 36 per cent. of nickel.

Certain alloys of different composition undergo curious changes when they are plunged into liquid air at a temperature of 180° below zero C. (292° below zero F.). A bar containing 30 per cent. of nickel, when thus heated, became permanently lengthened under the influence of the cold, instead of being shortened. The material underwent profound changes, as crystallizations indicating a transformation of the metal were seen to form on the polished surfaces. These investigations are of both scientific and practical interest.

CHEMICAL SECTION.

Stated Meeting, held January 29, 1903.

The Census of Manufactures of 1900.

By Charles E. Munroe.

Provisions for the periodic taking of a census was made at the founding of our Government; for Article I, Section 2, of the Constitution of the United States, directs that an enumeration shall be made within three years after the first meeting of the Congress of the United States, and within every subsequent term of ten years in such manner as they shall by law direct. The incorporation of this requirement in the initial law of our land has aroused much comment. Thus, De Jonnés has declared that the United States presents a phenomenon without parallel in history, viz.: "That of a people who instituted the statistics of their country on the very day when they founded their Government, and who regulated by the same instrument the census of inhabitants, their civil and political rights, and the destinies of the nation."

The taking of a census was not a new departure in government in 1787, for the Romans conducted full and minute enumerations, and it is with this people that the term "census" originated, but the United States was the first of modern governments to institute a system for the taking of a census periodically, and we have extended it to a degree not yet approached by others. As pointed out by Gen. Francis A. Walker, the framers of the Constitution, in incorporating in that instrument a provision for a national census, were not actuated by purely philosophical motives or by sentimental considerations, but the requirement was a political necessity arising from the representative form of government based on population as set forth and accepted in the Constitution.

For this reason at the outset an enumeration of the population only was contemplated, and the censuses of 1790 and

1800 were practically confined to statistics of this character, but with the machinery at hand there has been a constant tendency to put it to more extended use. The first enlargement of the scope of the census occurred in 1810, when the agents of the census were by law required to take account of the several manufacturing establishments and manufactories within their several districts. This extension was somewhat due to the influence of Alexander Hamilton, who, as Secretary of the Treasury, in 1791 submitted to Congress a "Report on Manufactures," which fairly represents the industrial situation in the United States shortly after the organization of the Federal Government, and just prior to the opening of the nineteenth century; but it was directly due to Albert Gallatin, who, as Secretary of the Treasury, in response to a resolution of the House of Representatives of June 7, 1809, made a report which is an admirable summary of the condition of American manufactures at that date, since, in concluding this report, Mr. Gallatin recommended that the law for taking the third census should be amended so as to require the marshals and their assistants to return an account of the several manufacturing establishments in their districts and divisions; and in accordance with this recommendation Congress, on May 1, 1810, passed an amendment to the Census Act authorizing the Secretary of the Treasury to appropriate for this return $30,000 out of the $150,000 set apart by the previous Act for taking the census. Thus it is to Albert Gallatin that the credit is due that the United States began thus early, and before any other country, taking a census of manufactures, and this practice has been continued uninterruptedly, with the exception of the year 1830, up to the present time. And in this Act we find the first official recognition of the dignity of labor and the important position that it occupies in the development of a nation. It is not possible to estimate the influence which this has exercised in enabling us to reach the commanding position that we now occupy.

Naturally, as in the carrying out of all new enterprises, the methods used at the outset for the collection of statistics of manufacture were crude and inefficient. Thus the

first industrial census of 1810 was taken without even the formality of a schedule, or definite instructions to the marshals, and necessarily the result forms no true measure of the industrial resources of the country at that time. In fact, the censuses of manufacture prior to 1850 were so imperfectly taken and compiled that it is not possible to use their data for purposes of exact comparison with the data of subsequent censuses. Certain of these reports even showed no aggregates for the United States or for each industry. Yet, nevertheless, they were useful in that they gave much valuable information regarding the industrial conditions and progress of the country.

For instance, in his Report on Manufactures, after enumerating seventeen different industries that were in 1790 carried on as trades in different localities, Hamilton describes a vast scene of household manufacturing, pointing out that cloths of woolen, flax and cotton and of mixed fibers, of many descriptions, for clothing and coverings, were "made in the household way, and, in many instances, to an extent not only sufficient for the supply of the families in which they are made, but for sale, and even, in some cases, for exportation. It is computed in a number of districts, two-thirds, three-fourths, and even four-fifths of all the clothing of the inhabitants is made by themselves. The importance of so great a progress as appears to have been made in family manufactures within a few years, both in a moral and political view, renders the fact highly interesting." The factory system of manufacture, so-called, in contrast to domestic and shop manufacture, had practically no existence in the United States at the opening of the nineteenth century. This system obtained its first foothold in the United States during the period of embargo and the War of 1812. The manufacture of cotton and wool passed rapidly from the household to the mill; but the methods of domestic and neighborhood industries continued to predominate, even in these industries, down to and including the decade between 1820 and 1830; and it was not until about 1840 that the factory method of manufacture extended itself widely to miscellaneous industries, and began mark-

edly to force from the market the hand-made products with which every community had hitherto chiefly supplied itself. Apparently, until about the year 1850, the bulk of general manufacturing was carried on in the shop and the household by the labor of the family or individual proprietors, with apprentice assistants, rather than by the present system of factory labor compensated by wages and assisted by power. Though the census of 1850 is the proper starting point for the comparative statistics of manufactures for this country, it is not possible to so analyze the figures returned by that census as to determine with certainty the relative proportion of the products of factories to those of the household and the neighborhood shop; yet the statistics of subsequent censuses demonstrated that since that date the relative value of the products of the factories have steadily increased, until at the census of 1900 the value of the products of the shop and household represents but an insignificant part, say one-thirteenth, of the total value of the products.

During this period there has grown up a division of labor which has promoted efficiency and speed of production through specialization, and also the so-called system of interchangeable mechanism, which is distinctively and peculiarly American in its origin. And by the segregation of labor in factories, together with the abundant use of machinery, has come a continued diminution of the cost of manufacture, while economies have been effected that were not possible under the older systems. To note the advantages of the division of labor we have but to compare the modern shoe factory with the older shoemaker's shop, or the modern establishments for slaughtering and meat-packing, with the household methods formerly universally in vogue. In these last-mentioned establishments we have also a striking example of the almost complete prevention of waste of which the factory system permits. Of the system of interchangeable mechanism Prof. W. P. Trowbridge has said in the Census report for 1880: "The general growth of the 'interchangeable system' in manufacturing has had an influence in the development of manufacturing, agriculture and

other industries which but few have hitherto appreciated. It may not be too much to say that, in some respects, this system has been one of the chief influences in the rapid increase in the national wealth. Two of the great industries, which constitute the basis of this wealth—agriculture and manufactures—depend now largely upon the existence of this remarkable feature in manufacturing, which has reached its highest development in this country. The growth of the system is due to the inventive characteristics of our people, and their peculiar habit of seeking the best and most simple mechanical methods of accomplishing results by machinery, untrammeled by traditions or hereditary habits and customs."

The means and methods employed in the gathering and presentation of the statistics of manufactures, which is the most difficult and complicated branch of census work, have, as shown in the History and Growth of the United States Census, 1790–1890, by Carroll D. Wright and William C. Hunt, been most varied. The direction has been put successively under the President of the United States, the Secretary of the State, the Secretary of the Treasury and finally in 1850 under the Secretary of the Interior, with whom it has since remained. By the law providing for the census of 1880 a census office was established in the Department of the Interior, and a Superintendent of the Census to be appointed by the President, by and with the consent of the Senate, specifically provided for. Up to 1880 all the statistics of every kind called for were collected under the supervision of the marshals of the United States courts through assistants appointed by them; but the law of 1880 entrusted this duty to a body of officers especially chosen for the work, to be known as Supervisors of Census. Their number was more than twice that of the marshals then in office, and this Act provided the means for securing not only a higher degree of local knowledge on the part of the supervisor, which was of great value in the subdividing of his district, but also a closer and more direct supervision of the actual work of enumeration. They were charged with the selection and instruction of the resident enumerators, the scrutiny of

their returns and the transmission of these returns to the office. This law further provided that the schedules of manufactures could be withdrawn from the enumerators of the several subdivisions, whenever the superintendent should deem it expedient, and the collection of these statistics charged upon experts and special agents to be employed without respect to locality, and under this provision the schedules for manufacturing industries were withdrawn in 1880 from the enumerators in 279 cities and the taking of these statistics given to special agents, while expert special agents were designated to collect statistics relating to certain specially selected industries of importance throughout the country. These expert special agents were further charged with the classification and analysis of the returns for these selected industries and the preparation of reports upon them which were published as monographs.

The schedules or blank forms containing the interrogatories upon which to take the returns, have likewise varied. In 1810 and 1820 a separate schedule for manufactures was used. In 1840 one schedule was used in common for statistics of mining, commerce, agriculture, manufactures and fisheries; in 1850, 1860 and 1870 one schedule was used in common for manufactures, mining and fisheries. In 1880 there was not only a return to a schedule for manufactures alone, but, as the law permitted special inquiries into selected industries, special schedules were introduced, there being forty-nine such special schedules and one general schedule used. In 1890 there were seventy-six special schedules and one general schedule for statistics of manufactures, while in 1900 there were thirty-two special schedules besides the general schedule. In the special schedules even, there has been a lack of uniformity in the different censuses, both as regards the industries selected and the queries that were put. Thus in 1890 the electrical industries alone were given twenty-seven special schedules, on which 2,240 questions were asked, while prior to this date there was no separate schedule for this industry, and in the census just completed there was but one supplemental schedule for it, containing eighteen questions. These are

but a few among the many variations in means and methods of the different censuses, which were largely due to the temporary nature of the work; to the clamor for detailed data on a wide variety of subjects; to the absence of trained advisors and to the character of the legislation under which the enterprise was carried out at each decade. As pointed out by Director Merriam in the *North American Review* for January, 1900, "The indications are that, in the decades that are past, as the time approached for making the required enumeration, the plan for doing the census work was always hastily devised, and thus a temporary and spasmodic atmosphere was given to the whole enterprise. It seems to have been the idea of those who shaped the census legislation in the past that the work did not need any well-defined plan, but that a large temporary force could be gathered together, and the information concerning population, agriculture and manufacturing industries and other subjects collected and reported to the country within a short space of time."

Nevertheless, there has been a constant effort at improvement, especially beginning with the census for 1880, for the collection of general statistics by enumerators and supervisors; the withdrawing of schedules of manufactures from the enumerators and the substitution of special agents in the more important manufacturing centers; and the employment of experts in making special investigations then introduced has been continued and extended, so that whereas in 1880 there were 279 cities withdrawn, 373 special agents employed to collect these statistics and nine expert agents to conduct statistical investigations, in 1890 there were 1,042 cities withdrawn, 1,383 special agents and assistant agents, and thirteen expert special agents, and in 1900 there were 1,340 cities withdrawn, 1,891 special agents employed and twenty-two expert agents engaged in researches.

The Act of March 3, 1899, under which the twelfth census was conducted, is regarded as being decidedly the best law that has ever been enacted for the taking of a census. By it the executive and statistical branches of the work were so sharply defined as to make the person in charge of each in-

quiry responsible for lack of method or tardiness in securing results. Under the Act there was appointed a Director who had the general charge of the administration, an Assistant Director, who is a trained statistician, to whom was assigned the general oversight of the various statisticians employed in the Bureau; five Chief Statisticians, to each of whom a certain line of inquiry was assigned, and for the manner and method of execution of which he was held responsible; Expert Special Agents and Special Agents as required; and five Expert Chiefs of Division besides the necessary clerical force. The Act creating the Bureau, for the first time in the history of census legislation, prescribed absolutely a time limit, namely, two years, for taking the statistics, arranging and analyzing them, and publishing the results for the census topics proper; population, vital statistics, agriculture and manufactures. These final volumes by this law constitute the "census reports" for the twelfth census. On the completion of this census the Act provided that the Census Bureau should then collect statistics relating to special classes, including the insane, feeble-minded, deaf, dumb and blind; to crime, pauperism and benevolence; to deaths and births in registration areas; to social statistics of cities; to public indebtedness, valuation, taxation and expenditures; to religious bodies; to electric light and power, telephone and telegraph business; to transportation by water, express business and street railways; and to mines, mining and minerals, it being prescribed that the reports relative to mines, mining and minerals should be published on or before July 1, 1903, and that the reports on all topics other than population, vital statistics, agriculture and manufactures are to be styled special reports. The mere recounting of these topics indicates how greatly the scope of the census has become enlarged from the simple enumeration of population as required by the Constitution.

This tendency to extend the inquiries has been observed from the beginning, for the Act under which the first census was taken called not only for an enumeration of all inhabitants (excluding Indians not taxed), but also required the marshals to distinguish the sex and color of free persons and

to separate the free males of sixteen years and upwards from those under that age; the latter requirement being undoubtedly for the purpose of ascertaining the military and industrial strength of the country. An effort to make the census for 1800 the vehicle for ascertaining sundry facts highly interesting and important to society was set on foot previous to the enactment of the law under which that census was taken. Two memorials to that end were submitted to Congress. One from the American Philosophical Society was signed by Thomas Jefferson as its president, and begged leave to submit to the wisdom of the legislature the expediency of requiring, in addition to the table of population, as in the former Act, "others presenting a more detailed view of the inhabitants of the United States under several different aspects." The second, from the Connecticut Academy of Arts and Sciences, signed by Timothy Dwight, its president, recited the fact that it was the belief of the memorialists "that to present and to future generations it will be highly gratifying to observe the progress of population in this country, and to be able to trace the proportion of its increase from native Americans and from foreigners immigrating at successive periods; to observe the progress or decline of various occupations; the effects of population, luxury, mechanic arts, the cultivation of lands, and the draining of marshes on the health and longevity of the citizens of the United States;" and to this end each asked that data be taken and classified so as to show the age, sex and condition of the inhabitants, their nativity, their occupations or professions and their location. Little immediate notice seems to have been paid to these memorials, though the statistics taken were extended to include five age-classes; but in the following census of 1810, as before stated, the inquiries were enlarged to include statistics of manufacture, and with the machinery at hand and the precedent established, the statistician, the economist, the sociologist, the humanitarian, the publicist, the capitalist, the man of science, all who sought information regarding peoples and their activities on a large scale, have sought to put this agency to further uses, especially since 1840, until it has

come to embrace an enormously wide range of topics. This extension has been seriously criticised. It has been said of the periodical census that, "as it has widened, it has weakened. More has been put upon the enumerator than he could well carry. His attention has been distracted by the multiplicity of objects presented, while the great number of inquiries has also perplexed and irritated the body of citizens." It has been charged that the added topics of inquiries exceeded the constitutional requirements; that the results are below the truth, and that they are necessarily incorrect because of the failure to complete the enumeration in a single day.

Taking these criticisms up in the reverse order, it may fairly be claimed that the criticism as to the length of time applies primarily only to the statistics of population. With the census of manufactures the conditions are such that it has no force; its data refer to a definite period and not to a date (as, for instance, in the twelfth census to the year ending June 1, 1900); its returns may be compiled from the records already made and existing in the factories; and changes in the number of establishments before or after that initial and final date cannot affect the established result.

As to the results presented being below the true ones, it is to be said that there seems to exist in man a natural inclination to overestimate and to magnify. According to Walker, the results of the first census of population, taken in 1790, like those of the first British census taken in 1801, was a great disappointment to the people of each of these countries, and dissatisfaction at the methods of enumeration was loudly expressed. Even Mr. Jefferson, as Secretary of State, when sending copies of the published tables abroad, was careful to impress it on the minds of his correspondents that the returns fell far short of the truth. The results of later censuses, however, established the substantial accuracy of the first enumeration, and showed that the dissatisfaction felt at the time was but the inevitable disappointment of over-strained anticipations. "To count," says Dr. Johnson, "is a modern practice; the ancient method was to

guess; and where numbers are guessed, they are always magnified."

As to the criticism that any inquiry beyond the mere enumeration of population exceeds the constitutional requirements of a census, it may be admitted that this is true; but the constitution dealt in this particular only with the primary necessity. It did not prohibit further inquiries, and the extension of this system of taking a national inventory has been justified by the results.

The criticism as to the burden put upon the enumerator and the weakening of the system through overloading has been well taken. It is less pertinent since the custom of detailing special agents to collect manufacturing and other statistics, and expert special agents to conduct special investigations, has come into vogue, and the perplexing and irritation of the people has also been lessened by the employment of agents who more clearly understood the nature, objects and relations of the interrogatories and so were able to properly explain them when the queries were not clearly understood.

All these criticisms were known and appreciated when the law, under which the census of 1900 was taken, was enacted and the division of manufactures organized, and provision was made for avoiding the errors pointed out so far as was possible. One fact that was especially impressed on the minds of those who planned the work was the futility of making the inquiries very detailed and minute. The experience with the electrical industries for 1890, alluded to above, was a striking example of this kind, as this elaborately planned investigation came to naught.

The Census Office, established under the Act of March 3, 1899, was organized by the appointment of Hon. William R. Merriam as Director; Dr. Frederick H. Wines, Assistant Director; William C. Hunt, Chief Statistician for Population; William S. King, Chief Statistician for Vital Statistics; S. N. D. North, Chief Statistician for Manufactures; LeGrand Powers, Chief Statistician for Agriculture; Walter F. Wilcox, Chief Statistician for Methods and Results; and Henry Gannett, Geographer. Each of these chiefs was chosen for

his well-known ability in handling the particular subject assigned him, and each had a reputation for capacity and thoroughness in his special line of inquiry. Mr. North, the Chief Statistician for Manufactures, had long been known as a student and authority on statistics of manufacture. Beginning on the staff of the Utica *Morning Herald*, in 1869, he rose to the editorship of the Albany *Express*, which he resigned in 1888 to accept the position of Secretary of the National Association of Wool Manufacturers and editor of its Bulletin. He served as expert special agent in the eleventh census; as an efficient member of the Industrial Commission appointed by President McKinley, and in other public capacities. His experience and reputation warranted the belief that the results achieved in this census of manufacture would prove to be of great value and to possess unusual reliability and fullness, and these expectations have been fully realized.

In the organization of the division the first effort was to secure, so far as possible, a clerical staff of experienced men. This was by no means a simple matter, as, notwithstanding repeated protests, Congress has always enacted legislation as if it regarded the census work as a temporary undertaking, and it has permitted the force assembled for each census, after it has become trained and experienced, to be widely scattered and absorbed elsewhere as soon as the work was closed. Among the efforts made to prevent the recurrence of this practice were those of the American Economic Association and the American Statistical Association, which, through a joint committee in 1896, presented a memorial to Congress calling attention to the importance of at once establishing a permanent and independent census office. The memorialists state that in doing so they are actuated by an earnest desire for the scientific development of statistics in the United States; that they represent learned societies whose members come, through their professional duties, in constant, almost daily, contact with the point of view of those who use statistics, and that it is in the general interest that they plead for methods of census administration which would tend to increase its efficiency

and heighten the value of its results. And in this connection the memorialists further say:

"In many departments of statistical work the publications of the United States Government occupy an honorable place. Through the liberal provision which has been made in the past for statistical inquiry, the United States has been able to contribute substantially to the development of statistical methods and to the extension of statistical research. But the work of the Government is uneven and sometimes fails to reach the highest standard. This is true of the census, the largest statistical undertaking of the Government, upon which money and effort are so generously lavished. There cannot be a moment's doubt that this work should be brought to the highest possible standard of statistical excellence.

"It is no reproach to the census as a whole, nor to the gentlemen who have administered the census office, to say that in many respects the census reports are unsatisfactory to us as students of statistics and to the people of the United States.

"We allude particularly to the attempt to cover too much ground, the enormous cost of the undertaking, and the delay in the publication of the completed tabular results. These criticisms all grow out of the legislation under which the census is taken. The defects of our present organization may be summarized under the following heads:

"(1) *Accumulation of inquiries at the same period of time.*

"(2) *The lack of continuity in the census work.*

"(3) *The haste with which the whole machinery of the census is placed in motion.*

* * * * * *

"The permanent and independent census furnishes the best guarantees for improvements in statistical work, if established under proper conditions. But it would be a grave misforture to postpone the organization of such a bureau until shortly before the time for taking the next census. We cannot urge too strongly that consideration be given at an early date to this question. If, as it should, the census of 1900 is to be an advance over those of preced-

ing years, thorough preparation for the work is indispensable. We are convinced that the gravest difficulty which has hitherto impeded the work of the census is the haste with which it has been planned and executed.

"It is not alone in the interest of statistical science, but in the interest of the public, which has an undoubted right to the most accurate and prompt information which the census office can furnish, that we urge the adoption of a measure which will attain this end and mark distinct progress in the statistical work of the Government."

Notwithstanding this earnest memorial and this wise advice, nothing was then done by Congress, and the twelfth census, like its predecessors, was organized on a temporary basis; but wiser counsels have since prevailed, and by Act of Congress of March 6, 1902, the Census Office was put upon a permanent footing from July 1, 1902, and the evils which have been charged to a temporary organization must henceforth be eliminated. Fortunately, owing to their superior character, a fair number of the trained employees of the previous temporary censuses have, when the work was closed, been transferred to other departments of the Government, and from such men a nucleus for each new census has been formed.

With such a nucleus to preserve the traditions, to which clerks selected by examination was added, the Division of Manufactures for the census of 1900 began the classification of industries, drafting of schedules, securing addresses of establishments and in general making preparation for the field work. In making the classification and in drafting the schedules every effort was made, while complying with the law of 1899, to adhere to the forms used in preceding censuses so far as possible, as all changes of classification are to be regretted since they made it difficult and at times impossible to trace the development of a given industry through successive census periods. It is true, of course, that certain changes are unavoidable because of radical modifications which take place in the various processes of manufacture; but it is safe to say that the majority of such changes as have been made in the past have not

been due to this cause, but to repeated changes in the office force with whose chief officers this question of classification has rested. By the system adopted the industries were divided into 354 different varieties and these were combined into fifteen groups. The first step is in accordance with that followed in the census of 1890, though there were then 369 varieties recognized. Such a classification, although necessary and proper, is not sufficient to present a clear, intelligible and scientific view of the general character and distribution of our manufacturing industries. It results in an alphabetical arrangement, which may be described as a statistical conglomerate, through which the student has to pick his way, making his own combination as he goes.

To remedy this defect the twelfth census has also brought the industries of the country together in fifteen grand groups. In making this generic grouping the effort has been to follow lines distinct and well recognized in common practice. The hand trades are set off into one group, and the true manufacturing industries are collected into groups distinguished either by the chief components employed as raw material, or by similarity in the use of the products, or by both. This grouping is found to embrace all but a comparatively small number of industries, which are classed together as an independent group.

Statistics, like other branches of investigation, reaches the point where it may properly be called scientific, only when the fundamental resemblances of individual phenomena are noticed, for then the former haphazard knowledge becomes organized knowledge. By the scheme adopted in this census the 354 industries correspond, in a measure, to the "species" of natural history, while the fifteen great groups of industries are analogous to the "genera," the whole making the great "order" of manufacturing industry. Thus viewed, we have as the subject of investigation the great order of manufacturing industry, made up of the fifteen genera or group of industries, each utilizing a common material or subserving a common purpose. These family groups ramify into the 354 various industries, each in turn being made up of the individual establishments.

The introduction of this system of grouping and its application to the statistics of this census, while rendering these readily available, in no measure prevents ready comparison with the available statistics of previous censuses; for, having formulated a grouping of the various industries which shows their relations and interdependence, it becomes possible so to apply the rule of selection and aggregation to the results of prior censuses as to show comparative statistics for each of the groups of industries.

Prior to the commencement of the field work a card catalogue was prepared of all establishments of productive industry throughout the United States of which a record could be found. In this work city directories were utilized, supplemented by trade directories, the reports of factory inspectors, the lists of commercial agencies, records of technical journals and notices of new factories supplied by newspaper-clipping bureaus.

The cards thus prepared for each of the greater cities were numbered and forwarded to the chief special agent of each city, who was required to return every card marked to show whether a schedule had been secured for the establishment, and if not, the reason why, as "burned," "removed," "not manufacturers," etc. The cards for the smaller cities were retained at the office, and the schedules as received were checked upon them. When the local agent announced his work complete, he received from the office transcripts of all cards for which schedules had not been received, and was required to furnish the missing returns or supply a satisfactory reason why they could not be obtained. In this way the office possessed a complete check upon the work of every special agent, and was able to secure a more thorough and satisfactory canvass than had ever before been obtained.

[*To be concluded.*]

Mining and Metallurgical Section.

Stated Meeting, held March 28, 1903.

A Study of Alloys Suitable for Bearing Purposes.

By G. H. Clamer.

Among the many problems presented to motive-power officials, there remains one of special interest which has lacked the scientific research which is its due. I refer to the metallic alloys suitable for journal brasses. There is no more important subject for investigation. The successful operation of rolling-stock in a great measure is dependent upon the bearings.

Much uncertainty exists as to what is the best constituted alloy for this particular service. Hundreds of formulas have been recommended, and ninety-nine out of each hundred founded upon the grand principle of "guess."

At first glance it may appear an almost hopeless task to even surmise which alloy is best constituted for such service; but upon closer examination we find that but few metals are available. They are as follows:

Copper, tin, lead, zinc, antimony.

It is true that other metals and metalloids may be introduced in varying small proportions, either with or without some material advantages, but the above five metals constitute the basis which may be used for the so-called anti-friction alloys. The combinations of the above metals, which to-day figure in service for this purpose, may be classed under two heads:

(1) White metals.
(2) Bronzes.

I. WHITE METALS.

(1) Lead, antimony.
(2) Lead, antimony, tin.
(3) Tin and antimony.
(4) Tin, antimony, copper.
(5) Tin, antimony, copper, lead.
(6) Zinc, tin, copper.
(7) Zinc, tin, antimony.
(8) Zinc, tin, antimony, copper.

II. BRONZES.

(1) Copper and tin.
(2) Copper, tin and lead.
(3) Copper, tin, lead and zinc.
(4) Copper, tin, zinc.
(5) Copper, zinc, lead.

The multiplicity of formulas recommended for journal brasses is evidenced by the table appended hereto, which is compiled by G. Charpy and published in his valuable treatise on the "Study of White Metals Called Antifriction."

I will confine myself in this paper more particularly to the study of alloys suitable for railway journal bearings, as this is perhaps the most important application of such alloys; furthermore, what applies here is in a certain sense true of all other applications.

It will no doubt be interesting to have before us the essential points to be considered in this connection:

(1) Composition.
(2) Structure.
(3) Friction.
(4) Temperature of running.
(5) Wear on bearing.
(6) Wear on journal.
(7) Compressive strength.
(8) Cost.

It is an utter impossibility to have one alloy reach the pinnacle of perfection in all the above requirements, as I shall later demonstrate; for example, the metal showing the slowest rate of wear may have the highest coefficient of friction, or the metal with the lowest coefficient of friction may have the greatest rate of wear, etc.

If it were possible to reach mechanical perfection in the adjustment of bearings it would be of little consequence what alloy or metal were used, providing the same had sufficient strength to support the load without deformation. If perfect adjustment were possible we would have at no time metal in contact with metal, but simply metal in contact with oil, the friction would be essentially fluid friction and abrasion due only to the wear of fluid against solid. But,

unhappily, such a state of perfection can scarcely be reached, and never will be reached in railway journal bearings, where end thrusts, lateral motion, reversal of direction of motion, etc., are continually encountered. Such being the existing state of affairs, the above tabulated qualifications must be studied and each balanced against the other according to its importance.

First and foremost qualification is that the alloy have the best composition, all things considered, to make the bearings—on this depends all the following essentials.

(2) On the composition in a great measure depends the structure. It is true that heat treatment and certain manipulation may affect the structure of the same compositions, but this effect is more particularly upon the size of crystals, etc. What is here meant by structure is the characteristic structure of a certain combination of metals; for example, the binary alloy, antimony and lead. This consists of crystallites of lead imbedded in a matrix of eutectic if the percentage of antimony be below thirteen, and, if above thirteen, consists of eutectic and free crystals of antimony. It has been shown that a successful bearing alloy must consist of at least two structural constituents—one hard constituent to support the load, and one soft constituent to act as a plastic support for the harder grains. Generally speaking, the harder the surfaces in contact, the lower the coefficient of friction, and the higher the pressure under which "gripment" takes place.

It would seem for this reason, the harder our bearing alloy, the better. It was with this idea in mind that alloys of copper and tin were so extensively used in the early days of railroading. A hard unyielding alloy for successful operation must, however, be in perfect adjustment, a state of affairs unattainable in the operation of rolling-stock. In order to obtain a proper adjustment of bearings when first applied in service, Mr. Hopkins many years ago introduced his lead-lined bearing. The practice of lining bearings has now become almost universal in this country. But notwithstanding that the bearing by this method obtains a good seat on the journal, the adjustment is constantly dis-

turbed, and the bearing proper must have a certain plasticity of its own to avoid heating when called into service to support the load.

In order to secure this plasticity, lead was introduced into the copper and tin alloy, and with excellent results, but this I will treat more fully later.

Much can be said regarding the causes of excessive heating of journal-bearings, but this is a subject which has been thrashed and rethrashed so often, that I will not attempt to go into the matter any further than to discuss those causes which are directly due to the brass itself.

(3) The third consideration in connection with our determination of the most suitable alloy is friction. Friction is dependent upon the composition and structure of the alloy. As stated, generally speaking, the harder the metals in contact, the lower the coefficient of friction; thus the class of bronzes have a lower coefficient of friction than the babbitt or white metals. At the same time, the harder the metal, the greater the liability of heating, because of the absence of plasticity (the property a metal has of molding itself to irregularities on the journal, and the consequent maintenance of a large area to carry the load). A hard unyielding metal under the above conditions will cause a concentration of load upon one or more high spots, and so cause an abnormal pressure per square inch on such areas, with the result that rapid abrasion and heating soon result. A hard unyielding bearing is a theoretical delusion, much to be desired, but impracticable of application.

Structure of the alloy plays an important part, as hard spots caused by oxidation, etc., frequently cause an irritation of the journal with a simultaneous production of abnormal friction and temperature.

(4) Temperature of running is of importance for determination, in so much that the amount of oil consumed is greater, the higher the temperature, but at the same time the lower the friction, providing the bearing is running under normal conditions. This is true only when comparing the same bearings under different temperatures, because the higher temperature may be caused by increased friction.

Generally speaking, the bronzes under the same conditions of pressure and speed will operate at a lower temperature than the softer metals, all things being equal.

(5) Wear of bearing. It is quite remarkable the relation existing between composition and wear. This presents a wide field for research—a field almost unexplored. High-priced compositions are being used, which have but little resistance to wear compared with cheaper compositions, and low-priced alloys are in service that are not cheap at any price. But very little data is to be had on this score, for the reason that such tests in service require a great deal of time, and a satisfactory laboratory machine has not until recently been designed. A machine which the writer has used for the past two years has given good satisfaction, and will be described shortly.

(6) Wear on journal. Composition of the bearing has a decided effect upon the wear of the journal; but whether the difference in the rate of wear is due directly to the composition is a disputed point—no positive proof to this effect is attainable. It is generally conceded that the soft metal bearings cause a marked decrease in the life of journals. Now, as to whether this is due to the imbedding of grit on the bearing surface, with the consequent formation of a lap, or to the fact that the metal itself has a dragging nature, I am not prepared to say. In a recent paper by Mr. David Van Alstine, some statistics were given on the life of journals, which I think will be interesting here.

(1) *Tender Axles* for ½-inch wear—490,000 miles—5 per cent. removed for collar wear.

(2) *Engine Truck Axles* for ½-inch wear—245,000 miles.

(3) *Driving Axles* for ½-inch wear—476,800 miles.

(4) *Freight Car Axles*—274,000 miles—29 per cent. removed on account worn collars.

(5) *Passenger Car Axles*—504,000 miles—94 per cent. removed on account collar wear.

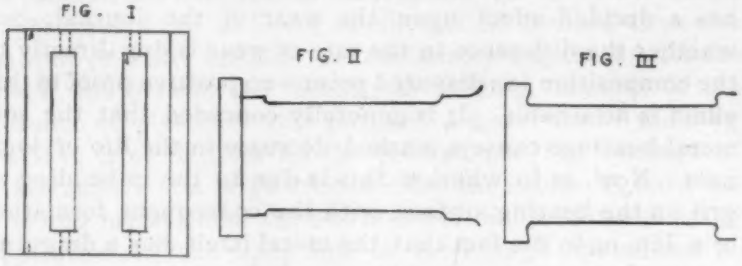
Mr. Van Alstine attributes the low mileage shown by English truck axles as due to the fact that these are babbitted brasses.

Driving axles, he declares, have a tendency to wear tapering and hollow. This he attributes to the uneven distribu-

tion of dirt in the packing. Uneven wear is caused in many cases, however, by the use of babbitt strips across the bearing surface; the tendency to wear hollow, at any rate, can be traced to this cause. Observations to this effect have been made by a number of prominent railroad men and recited to the writer. In one instance the strips were set according to the usual practice, only over a portion of the surface as shown in *Fig. 1*, which is a view looking down on an inverted brass.

The result of the uneven wear on the journal was that a depressed area plainly marked the increased rate of wear due to the babbitt strips. *Fig. 2* is a slightly exaggerated view of the appearance of such an axle.

To remedy this defect the babbitt strips were allowed to extend across the entire surface; the result was an even but



proportionately greater rate of wear. Owing to the above conditions prevailing and the fact that babbitt often becomes so heated as to melt and run out, causing frequently serious trouble, is a good argument for the abandonment of such practice.

The low mileage of freight-car as compared with passenger-car axles is attributed to the fact that they receive less attention, which is quite plausible, ill-fitting lids and dust-guards allowing more dirt to enter the box and cause abrasion. It is surprising to learn that 94 per cent. of the passenger-car axles are removed on account of worn collars. This state of affairs may, without much hesitation, be laid to the lead lining of brasses lapping out the fillets. That such is the case is an undisputed fact, and has come to the

notice of all observing motive-power officials. Fillets are not only worn to a right-angle, but are often cut in as is shown in *Fig. 3*.

Compressive Strength.—A test of the compressive strength of alloys intended for use as bearings is of importance in indicating—

(1) If the alloy is hard enough to support the load without deformation.

(2) If the alloy is brittle and will split under effects of pressure.

(3) If it is sufficiently plastic to reasonably suppose it will run cool under aggravated conditions.

Now, having briefly discussed the qualification of the bearing metal, let us take up the various combinations of metals as previously classified and study their characteristics.

(1) LEAD AND ANTIMONY.

These metals will alloy in any proportion, with increase of antimony the alloy becoming harder and more brittle. The combination of these two metals, however, which alone is exempt from segregation, is that of the eutectic mixture, which according to various authorities has been found to be approximately: lead 87 per cent. and antimony 13 per cent. Alloys with less than 13 per cent. show, upon microscopic examination, to consist of dendrites of pure lead imbedded in a matrix of eutectic. The structure of the alloy with the eutectic composition shows no segregated metals or alloys, and has a laminated structure characteristic of all eutectics consisting of laminæ of lead and laminæ of antimony.

With above 13 per cent. of antimony, free crystals of antimony appear, and, if the alloy is allowed to cool slowly, they rise to the surface, owing to the very low specific gravity, namely, 6·5, as compared with the specific gravity of the eutectic, which is 10·48.

The melting-points, as given by Stead, are for the segregated antimony about 615° C., and for the eutectic 247° C. It will be noted that the temperature of the eutectic is 78° below the conceded melting-point of lead—the most fusible

constituent; therefore in an alloy below 13 per cent. antimony, the lead crystallizes out of the still fusible eutectic in the form of so-called and well-known "Fir Tree" lead.

Alloys containing 10 per cent. antimony show upon the surface of a slowly cooled ingot the eutectic spherules and lead crystals.

Alloys containing less than 6 per cent. antimony show only lead crystals upon the surface, owing to the predominance of those which solidify over the eutectic.

According to Charpy, an antifrictional alloy should consist of hard grains, which carry the load imbedded in a matrix of plastic material, to give it the property of molding itself to the journal and its irregularities without undue heating. Such a condition is met in the alloys above the eutectic composition; but with increasing antimony the alloys become more brittle, and above 25 per cent. are unsafe in service for this reason.

Charpy further claims that alloys between 15 per cent. and 25 per cent. are best constituted for bearing purposes. I cannot quite agree with this, however, as the alloys containing below 13 per cent. antimony can likewise be said to consist of hard grains (the eutectic imbedded in lead), and it has been my experience that, although the friction may be higher in such alloys, the wear is greatly diminished, and where pressures are light, causing no deformation, this is a great advantage. I have seen many instances in service where alloys between 15 per cent. and 25 per cent. were greatly inferior to alloys between 8 per cent. and 12 per cent., owing to their frequent renewal due to wear.

It will perhaps be interesting to hear that the Pennsylvania Railroad Company, at the suggestion of Dr. Dudley, their chemist, have adopted the 13 per cent. antimonial lead alloy as a filling metal for bearings in order to obtain the best results.

The appended table compiled by Charpy illustrates the above facts, and these results in a general way are confirmed by our own work on the subject, viz.: that lead is the best wear-resisting metal known, and that with increasing antimony, or increasing hardness and brittleness, the wear

becomes more marked. This is due to the splitting up of the harder particles.

The friction, as we may naturally expect, becomes less with increase of antimony, and the temperature of running likewise diminished when running under normal conditions; but the harder the alloy, the more difficulty is experienced in bringing it primarily to a perfect bearing, and the greater the liability of heating through aggravated conditions. The wear on the journal one would naturally expect to be decreased with increasing hardness; but this journal wear is in all probability not due so much to the alloy directly as it is to the fact that the softer metals collect grit, principally from the small particles of steel from the worn journal, and, acting as a lap, causing rapid wear. With the harder metals these particles are worked out without becoming imbedded.

The cost of the above alloy is the least which can be produced. It can be used in many services where higher-priced alloys are being relied upon mainly for their high cost. It is one of the greatest extravagances of large industrial establishments to use goods which are too good for certain uses, and even perhaps unsuited, under the supposition that they must be good because they paid a good price for them. This fact has no greater exemplification than in the purchase of babbitt metal, and is due to the great uncertainty which exists, not only among consumers, but among manufacturers, many of whom carry on their business much the same as the patent-medicine man.

(2) LEAD, ANTIMONY AND TIN.

I do not wish it understood that antimony-lead is the cheapest alloy to use under all circumstances; not so, for when high pressures are to be encountered, tin is a very desirable adjunct. Tin imparts to the lead-antimony alloy rigidity and hardness without increasing brittleness, and can produce alloys of sufficient compressive strength for nearly all uses. The structure of a triple alloy of this nature is quite complicated, and not yet definitely defined.

Besides the existence of various metals in the free state,

or in solid solution according to the proportions in which they exist, there is a distinct chemical combination SbSn. The introduction of tin into the finely crystalline antimonial lead of commerce gives it a coarser grain, due to the formation, no doubt, of the cubical crystals of the above-mentioned chemical combination SbSn. The cost of the alloy increases with increase of tin; but for certain uses, where insufficient compressive strength cannot be gotten by antimony, because of its accompanying brittleness, it is indispensable, and will answer in nearly every case where the tin basis babbitts are used.

(3) TIN AND ANTIMONY.

This alloy, with 5 per cent. antimony, is shown to consist of free tin and a matrix of tin and antimony, probably of the formula SbSn or $SbSn_2$, as claimed by some investigators. The same is true of alloys containing up to 45 per cent. antimony, when the scattered crystals previously seen are brought closer and closer together, as in the lead-antimony alloy, until they are in close contact with each other, and probably have formed the compound Sb_2Sn_2. Tin and antimony are seldom used alone as bearing alloys, but are extensively used for so-called Brittania ware, and in equal proportions for valve seats, etc.

(4) TIN, ANTIMONY AND COPPER.

This combination is what is known as genuine babbitt, after its inventor, Isaac Babbitt, who presumably was the first man to conceive the idea of lining bearings with fusible metal. The formula, for no arbitrary reason, which he recommended is as follows:

Tin	89·1
Antimony	7·4
Copper	3·7

This formula is still considered the standard of excellence in the trade, and has been adopted by many of the leading railroads, the United States Government and many industrial establishments. It is used in the majority of cases where cheaper composition would do equally as well.

According to Behrens and Bauche, who have made ex-

tensive examination of this triple alloy, it is made up of rectangular crystals of an alloy of tin and antimony, a whitish bronze forming radial clusters or brittle rods composed of hexagonal flakes, the mother liquor or matrix being nearly pure tin. The cuboidal crystals are evidently 9 per cent. tin and 1 per cent. antimony, and the rods of whitish bronze 9 per cent. tin and 1 per cent. copper. This is the most costly of all bearing alloys because of the high content of tin.

(5) TIN-ANTIMONY-LEAD-COPPER.

This quadruple combination of metals I will not venture to describe, as it would no doubt take years of study to fathom the complicity of the metallic combinations here represented. Suffice it to say that lead, although of itself a soft metal, renders this alloy, when added in but small proportions, harder, stiffer, more easily melted and superior in every way to the alloy without it, and yet consumers will raise their hands in horror when a trifling percentage of lead is found in their genuine babbitt. This is one of the instances where cheapening of the product is beneficial.

The foregoing represents the more important combinations of alloys of tin and lead basis. These are of far more importance in the arts than the white metals, the main portion or basis of which is zinc.

At various times new combinations of zinc have been proposed, but so far as my knowledge goes, they have not come into popular use for two reasons. First, because of the great tendency of zinc to adhere to iron when even slightly heated. What is technically known as galvanizing the journal is effected under these conditions. Second, because of the brittleness produced under the effects of heat, such as is produced by friction when lubrication is interfered with and consequent danger of breakage. I will not discuss the various combinations of zinc separately, because, as I have already said, they present but little practical importance.

BRONZES.

Bronze is the term which originally was applied to alloys of copper and tin as distinguished from alloys of copper and

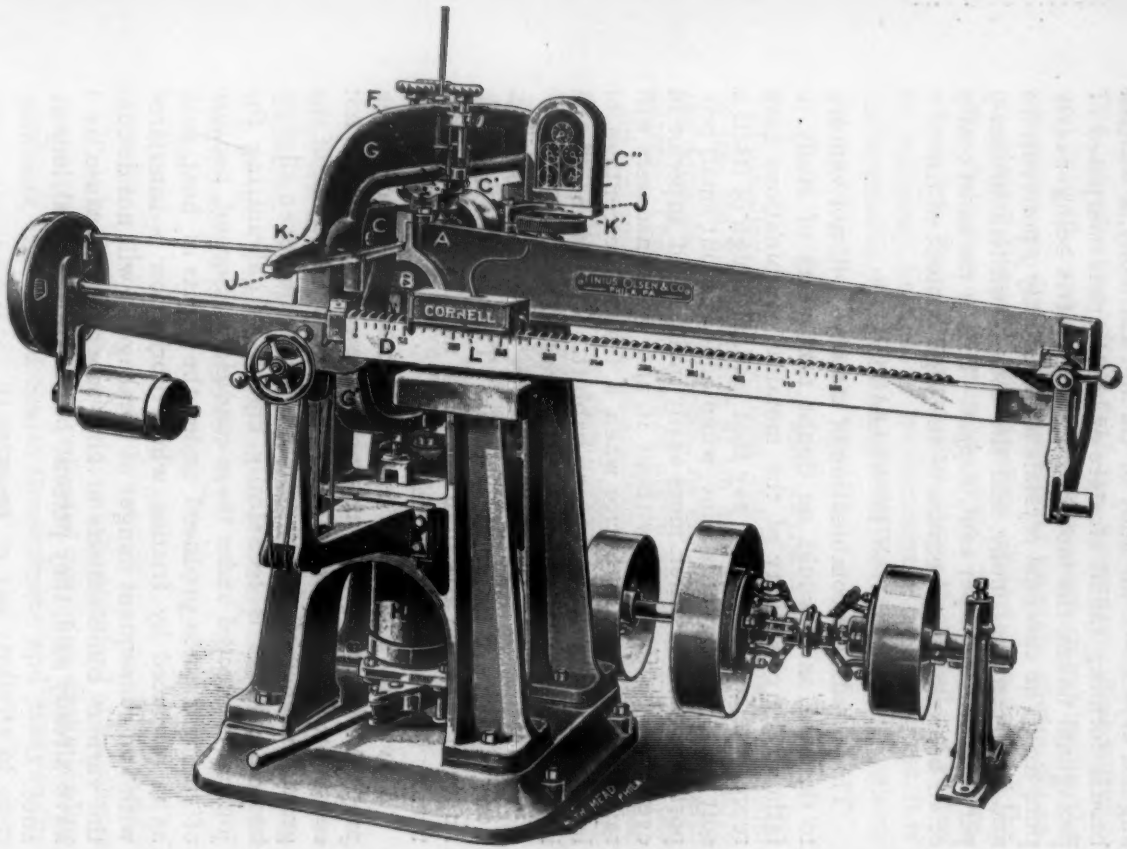


FIG. 4.—Professor Carpenter's testing machine. (Built by Tinius Olsen, Philadelphia.)

zinc; but gradually the term "bronze" has become applied to nearly all copper alloys containing not only tin, but lead, zinc, etc., and no sharp lines of demarcation exist between the two.

The tests I am about to describe were conducted on a testing machine designed by Professor Carpenter, of Cornell University, and built by Olsen, of this city. (*Fig. 4.*)

It consists of a journal *A*, which revolves on the large cast-iron wheel *B*, and held in position by the bearings *C*, *C'*, *C''*. The object of the wheel *B*, which revolves on the bearings *D* and *D'* is to take the pressure and thus relieve the bearings *C*, *C'*, *C''*, which would otherwise become heated and cause erroneous readings. The test bearing *E* is held in contact with the journal by means of the ball-and-socket joint *F*—the socket being on the bearing, and the ball on the adjustment screw supported in the knife edge lever *G* and *G'*. The load is put on the bearing by means of spring *H*, which pulls downward on knife edge *I*, and this in turn on the knife edges *J* and *J'*, and these against smaller springs *K* and *K'*. The pressure is recorded in pounds. The speed indicator and counter records the number of revolutions. The arm attached to lever *G*, by means of the screw-operated weight *L*, indicates the friction in pounds, or in other words balances the pull due to friction. A thermometer is placed in the hole in the bearing to record the temperature. This machine is compact and I have found it quite satisfactory.

The test bar I have adopted is 3½ inches long and ½ inch wide. This can be weighed on a delicate chemical balance, and from 100,000 to 500,000 revolutions will give a very perceptible wear. The data thus obtained:

(1) Loss of metal by wear obtained by weighing before and after test.

(2) Friction in pounds.

(3) Temperature of running.

The constants are:

Area of contact.

Pressure per square inch.

Kind of lubrication.

Method of lubrication.

FIG. 4.—Professor Carpenter's testing machine. (Built by Tinius Olsen, Philadelphia.)

The most satisfactory method of lubrication thus far found has been that of ordinary car lubrication, viz.: by means of waste held to the under side of the journal.

This machine has overcome many of the defects of the old Thurston machine and various others which are largely used.

Each of the alloys tested was subjected to chemical analysis and microscopic examination to obtain as complete a knowledge as possible of the alloys under consideration.

The first series studied is that of copper and tin.

COPPER AND TIN.

This, according to our general conception of the word, is a bronze only when the copper content exceeds that of the tin. According to the proportions in which the metals exist, it has widely different properties. In general, the tin hardens when present up to proportions of 30 per cent., or perhaps a little over, and when this limit is exceeded, it takes on more and more the nature of tin until pure tin is reached. From a scientific point of view this alloy is one of the most interesting and has attracted the attention of many investigators, who have spent years of study on it, to learn its various properties and explain its constitution. The investigators are Kunzel, Thurston, Charpy, Haycock, Neville and others.

The alloys which interest us most, however, are those which are so constituted as to be adapted for bearing purposes. These would be said to contain from 3 to 15 per cent. tin, and from 85 to 97 per cent. copper. The alloy of tin containing smaller percentage of copper is often used as a babbitt metal, but this comes under the class of white metals, which I have already discussed. Bronze containing above 15 per cent. of tin has been recommended at various times for bearings owing to its hardness, but very unwisely, for such a bearing assumes mechanical perfection and perfect lubrication. It has no plasticity of its own, and immediately as the oil film is interrupted rapid abrasion and gripment take place, with hot boxes as the result. The very erroneous idea is still held by many, that to resist wear

and run with the least possible friction a bearing alloy must be as hard as possible. It is true that hard bodies in contact move with less friction than soft ones; but the alloy which is the least possible to heat and cause trouble is the one which will stand the greatest amount of ill use; by this I mean an alloy which has sufficient plasticity to adapt itself to the irregularities of service without undue wear. The enthusiasts of hard bearings have even gone so far as to try glass for this purpose, and whereas this substance may give satisfaction on perfectly adjusted light spindles, for example the jewel bearings of a watch, we can readily imagine what would be the consequences if such a trial was made on locomotive or car journal bearings. It is for the foregoing reasons that I have limited the useful bearing alloys of copper and tin to those containing less than 15 per cent. tin, and began my investigation from this point.

The alloys of copper and tin I will treat in rather more detail, owing to the bearing which they have on the alloys which follow, rather than for their actual usefulness for the service.

These alloys were used extensively some twenty or twenty-five years ago, and were indeed considered the standard for railroad and machinery bearings. The old alloy, known as "Cannon Bronze," containing 7 parts copper and 1 part tin, is still being specified by some few unprogressive railroad men and machinery builders.

Copper 85 per cent., Tin 15 per cent.—Microscopic examination shows this alloy to be made up of chemically combined copper $SnCu_8$, dendrites of pure copper, and a large area of eutectic mixture, 73 per cent. copper, 27 per cent. tin, as given by several authorities.

The tests on the machine show the following:

Friction in pounds	13
Temperature above room, degrees F.	50
Wear, in grams	·2800

The friction, as naturally expected, is lower than that of any of the following alloys which were tested, they being all softer than the above. The temperature of running, being a factor of the friction, is likewise less. The wear, however,

is greatest of all, no doubt due to the large amount of hard brittle eutectic present (copper 73, tin 27).

Copper 90 per cent., Tin 10 per cent.—This alloy has the same general structure as the alloy of 15 per cent. tin, but differs in the greater amount of free copper and lesser amount of eutectic which it contains.

Machine tests:

Friction in pounds	13
Temperature above room, degrees F.	51
Wear, in grams	·1768

The friction was practically the same, temperature little higher than the foregoing, but the rate of wear slower, owing to the smaller amount of eutectic present, and its consequent softness.

Copper 95 per cent., Tin 5 per cent.—This alloy contains, beside the $SnCu_3$, large amounts of free copper, and but small amount of eutectic, especially if the alloy is quickly cooled.

Machine tests:

Friction in pounds	14
Temperature above room, degrees F.	52
Wear, in grams	·0776

Friction and temperature are here again higher, and the rate of wear greatly diminished.

To Dr. C. B. Dudley, chemist of P. R. R. Co., is due the credit of having done more for the establishment of good sound knowledge on the subject of bearing-bronzes than any one else. Dr. Dudley, in a paper which he read before the Franklin Institute in 1892, showed the relation existing between the tin and lead content of the copper alloy, and his determinations were founded on actual practical tests. In their relation to the tin content, are summed up in his own words, as follows: "The rate of wear diminishes with the diminution of tin." These determinations, it will be noted, are confirmed by my own work on the subject, and gives us a starting point on which we have based our knowledge for the production of a very efficient bronze for bearing purposes, presently to be described.

COPPER, TIN AND LEAD.

The copper, tin and lead-alloy is now recognized the standard bearing-bronze, and in the above-mentioned paper the fact was clearly established that lead introduced into the copper-tin alloy was a decided advantage; first, because the bearing containing lead was less liable to heat, under the same state of lubrication, etc.; and, second, the rate of wear was greatly diminished. Experiments were made in service which clearly demonstrated the above facts. It will no doubt be interesting to note the following table, which represents these results in classified form:

Metal Tested.	Composition.					
	Copper.	Tin.	Lead.	Phosphorus.	Arsenic.	Relative Wear.
Phosphor-bronze, standard	79·70	10	9·60	·80	...	1·00
Ordinary bronze	87·50	12·50	...	...	...	1·49
Arsenic bronze, "A"	89·20	10	...	...	·80	1·42
" " "B"	82·20	10	7·00	...	·80	1·15
" " "C"	79·70	10	9·50	...	·80	1·01
Bronze, "K"	77·00	10·50	12·50	...	...	·92
	77·00	8·00	15·10	...	...	·86

Three points will be noted: (1) The rate of wear diminishes with the decrease of tin, as above stated. (2) The rate of wear decreases with the increase of lead. (3) Arsenic and phosphorus apparently have no bearing on the wearing qualities. My work here again has been but of a confirmatory kind. Taking up the same thread, I began with the alloy of 5 per cent. tin, holding this constant in all following alloys examined, but increasing the lead 5 per cent. each time.

Copper 90 per cent., Tin 5 per cent., Lead 5 per cent.—Microscopically, this alloy shows the presence of pure copper, practically pure lead in mechanical admixture, and the copper-tin eutectic (consisting of copper and crystals of $SnCu_3$). I am not prepared to say if there also exists one

or more complicated eutectics; this is quite probable. I have some information bearing on this point, but as a discussion of this will be quite lengthy, will omit it here.

The lead, as naturally supposed, covers but a small portion of the field.

Machine test:

Friction in pounds	16
Temperature above room, degrees F.	53
Wear, in grams	·0542

Copper 85 per cent., Tin 5 per cent., Lead 10 per cent.—This alloy shows the same general characteristics as the foregoing, but a larger field occupied by the lead. The lead is clearly seen without etching, and is shown to be held in little pockets or network of copper and tin.

Machine test:

Friction	18½
Temperature above room	56
Wear, in grams	·0308

Copper 80 per cent., Tin 5 per cent., Lead 15 per cent.—Microscopically the same as above.

Machine test:

Friction in pounds	18½
Temperature above room, degrees F.	58
Wear, in grams	·0327

In view of the foregoing knowledge it seemed to be highly desirable to produce an alloy with as much lead and as little tin as possible, not only for the reason that such an alloy is less liable to heat in service, and at the same time show a diminished rate of wear, but also because the two expensive metals, viz.: copper and tin, are replaced by a far cheaper metal—lead.

The metal known as Ex. B. composition—tin 7 per cent., lead 15 per cent., copper 78 per cent.—was adopted as the result of Dr. Dudley's work, he stating that this alloy, according to their then present knowledge, was the best that could be devised, and I take the liberty of using the following quotation from his before-mentioned paper: "Some experiments have been made towards the still further diminution of tin and increase of lead, but it is found that a certain

amount of tin is necessary to hold the lead alloyed with the copper, and apparently the limit of diminution of tin and increase of lead is not a great ways from the composition of alloy B." Summing up the valuable knowledge as set forth by Dr. Dudley, appreciating fully the benefits to be derived, could a method be found of making successful castings on a large scale, with lower tin and higher lead content? We gave the matter careful attention, and carried on an elaborate series of experiments, but time will not permit me to go into details of same; but suffice it to say that the fact was discovered that a certain amount of tin was necessary for retaining the lead without segregation, and also to give the alloy requisite compressive strength, but that a greater amount is exceedingly detrimental. We were able to produce, without difficulty, alloys with 5 per cent. tin and 30 per cent. lead, but were unable to obtain castings containing 30 per cent. lead, if the tin exceeded 6 to 6½ per cent., nor could we produce castings with even slightly above 20 per cent., when 7 per cent. of tin was exceeded. This seemed very strange, as naturally one would suppose if a small amount of tin will hold a certain amount of lead, a larger amount should hold still more. The most satisfactory explanation we could find for this, and which is contained in our patent covering this alloy, is as follows: As I explained when discussing the copper-tin alloy, the same was made up of dendrites of copper, a chemically constituted alloy of copper and tin and eutectic—the eutectic being made up of laminæ of $SnCu_3$ and laminæ of copper, and being found by analysis to contain 73 parts copper and 27 parts tin, and having solidifying point of approximately 930° F., while the copper solidifies above 1,800°.

Now, as the tin is increased, the eutectic is increased, and one can readily imagine that when a large bulk of the alloy must cool down from the casting temperature above the melting-point of copper (to 930°) it must necessarily remain a long while in the liquid state in the mold. The lead, as I have shown, is but mechanically held by the network of copper and tin, and having a solidifying point more than 300° below the eutectic, has abundant opportunity,

owing to its high specific gravity, to liquate to the bottom of the casting, and this, in fact, is exactly what happens; but in the absence of eutectic, or in the presence of but small amount of it, solidification takes place soon after entering the mold, and forms the copper-tin network, which envelops and upholds the still liquid lead. This is evidenced by the fact that such castings may be withdrawn from the sand when still red-hot (far above the solidifying point of lead), and yet show no sweating of the above metal.

It is quite possible, on a small scale and under certain conditions, viz.: as in pouring into chill molds, to obtain fairly uniform alloys without adhering strictly to the proportions which we have claimed in our patent covering this alloy; but the proportions as here set forth are the only ones in which satisfactory castings can be made on a large scale—our claim being a bearing containing less than 7 per cent. tin and more than 20 per cent. lead, and the balance copper, substantially as described.

The results obtained by adhering to the above proportions, however, are not entirely what may be desired for every-day practice. The presence of some detrimental impurities or casting at a too elevated temperature often causes slight segregation. The thought now came to our minds to obtain some means of more rapidly chilling the castings. The casting in iron molds being entirely impracticable for manufacture of many miscellaneous patterns, made us seek for some better means. The thought came, is it possible to add some element directly to the alloy, which will have the desired effect? After going over the whole list of high-melting-point metals, nickel was found to be the only one which answers in a practical way. It unites readily with copper, and the presence of from ½ to 1 per cent. is found sufficient to cause a rapid setting of the cast metal; this forms the basis for a second patent bearing on the same alloy—a process for preventing segregation in the copper-lead alloy, which consists in adding thereto small proportion of nickel, substantially as described.

This alloy is now known in the trade as "Plastic Bronze," and has become a thoroughly commercial article. It has

been on the market hardly three years, but has been made in an amount which approximates 4,000,000 pounds. It has been cast in all manner of patterns, weighing from a fraction of a pound to over 1,000 pounds each, and is handled as readily in the foundry as phosphor-bronze, manganese bronze, or any of the more common alloys. Castings are sharp and clean. It machines readily, and, in fact, possesses all the qualifications essential for practical purposes.

Having accomplished the production of an alloy containing upwards of 20 per cent. lead, the next object was to test it in the manner of the previous ones, the tin being kept constant at 5 per cent.

Copper 75 per cent., Tin 5 per cent., Lead 20 per cent.—It will be noted that no nickel was used in the test bearings, as it was thought desirable to have no other elements present.

Microscopically the alloy showed the same structure—network of copper and tin, and large area mechanically held lead.

MACHINE TEST.

Friction in pounds	18½
Temperature above room, degrees F.	58
Wear, in grams	·0277

Copper 70 per cent., Tin 5 per cent., Lead 25 per cent.—Same as above.

MACHINE TEST.

Friction in pounds	18
Temperature above room, degrees F.	58
Wear, in grams	·0204

It will be noted the friction here is apparently little less than above.

Copper 65 per cent., Tin 5 per cent., Lead 30 per cent.—Microscopically examined, large portion of the field is shown to be covered by lead.

MACHINE TEST.

Friction in pounds	18
Temperature above room, degrees F.	64
Wear, in grams	·0130

The following table will show the above results in classified form, giving the exact formula of each alloy as determined by chemical analysis:

COPPER AND TIN, AND COPPER, TIN AND LEAD SERIES.

	Copper.	Tin.	Lead.	Friction.	Temperature above Room.	Wear, in Grams.
1	85·76	14·90	. . .	13	50	·2800
2	90·67	9·45	. . .	13	51	·1768
3	93·01	4·95	. . .	16	52	·0776
4	91·82	4·62	4·82	14	53	·0542
5	85·12	4·64	10·64	18½	56	·0380
6	81·27	5·17	14·14	18½	58	·0327
7	75?	5?	20?	18½	58	·0277
8	68·71	5·24	26 67	18	58	·0204
9	64 34	4·70	31·22	18	44	·0130

The conditions in all above-described tests were as follows:

Total number of revolutions made	100,000
Revolutions per minute	525
Size of journal, 3¾″ diameter, 3½″ long.	
Pressure per square inch in pounds	1,000
Lubrication—Galena coach oil, fed by cotton waste.	

Tests were made with higher-lead-content alloys, and also copper, lead and nickel alloys without tin, but time will not permit me to discuss these.

The alloy which we have adopted consistent with proper strength for general purposes and with the best foundry results is copper 64 per cent., tin 5 per cent., lead 30 per cent., and nickel 1 per cent.

It will be noted that what is true of the alloys of 15 per cent. lead and under, as examined by Dr. Dudley, is also true of the high-lead-content alloys, viz.: that the rate of wear diminishes with increase of lead, or, in other words, the rate of wear diminishes with the diminishing compressive strength or increased plasticity of the alloy. This alloy has plasticity resembling babbitt metals, and for this reason can fairly be expected to show a less tendency to become heated. This has been amply proven in actual service.

There remains several other classes of bronzes, which,

owing to their low cost of production, are largely used. They are alloys of copper and tin containing zinc, or containing both zinc and lead. Such alloys as these can be made from miscellaneous junk, and hence the low cost of production.

Foundry and machine tests have been made of a number of these, which brought out the following conclusions:

(1) Zinc increases the rate of wear.

(2) Zinc has a tendency to segregate lead.

The following table will be of interest in this connection. Effort was made to keep the tin and lead as constant as possible, and replace copper by zinc.

	Copper.	Tin.	Lead.	Zinc.	Friction.	Temp. ab. room.	Wear, in grams.
5	85·12	4·64	10·64	. .	18½	56	·0380
10	82·27	5·28	10·25	2·07	18½	68	·0415
11	79·84	4·71	10·30	5·44	18½	66	·0466
12	77·38	5·62	11·42	6·54	18½	68	·0472
13	74·28	4·68	10·61	11·04	18½	69	·0846

CONDITIONS—SAME IN ALL TESTS.

Total number of revolutions	100,000
Revolutions per minute	525
Journal 3¾ inches diameter, 3½ inches long	
Pressure per square inch in pounds	1,000
Lubrication—Galena coach oil, fed by cotton waste.	

These miscellaneous alloys, containing copper, tin, lead, zinc, iron and other metals, form a very large part of the present railway equipment in bearings, it having long been the practice to use junk of every conceivable variety in their manufacture. Materials which could not be used for any other purpose were considered good enough for car brasses; but railroad officials are gradually becoming educated to the fact that the best is none too good.

We have recently put in operation a patented process for the refining of copper-tin-lead alloys containing detrimental impurities, such as zinc, iron and other electro-positive metals. A description of this process will probably make the substance of a future paper.

In conclusion I wish to express my gratitude to Dr. Dudley for his valuable work preceding our own, for the test

which he has conducted in service of our plastic bronze bearings, and the many valuable hints which he has given me from time to time.

I also wish to acknowledge my gratitude to Charpy and Stead for their valuable work in the study of the constitution of alloys.

ALLOYS OF LEAD, TIN AND ANTIMONY.

Lead.	Tin.	Antimony.	References.
94	—	6	Alloy analyzed by Dudley.
88	—	12	Alloy analyzed by Dudley.
85	—	15	Quoted by Hiorns (soft alloy). Quoted also by Dudley.
84	—	16	" " Ledebur. For slow-revolving pulleys.
86	12	8	Used by Eastern Railroad (France) for metallic packings.
77·7	5·9	16·8	Quoted by Thurston, as being the composition of Magnolia and Tandem metals.
76	14	10	Used for metallic packings by the Orleans and P. L. M. Railroads.
73	12	15	Metallic packings of piston rods. Northern Company (France).
70	20	10	Metallic packings of eccentric collars. French state railroads.
68	15	17	Graphite (?) metal analyzed by Dudley.
60	20	20	Quoted by Ledebur. Railroad bearings.
42	46	12	" " Hiorns. Hoyles metal.
42	42	16	" " Ledebur. Journal boxes. French state railroads.
40	45	15	" " Ledebur.
37	38	25	" " Thurston. Italian railroad companies.

ALLOYS OF TIN, COPPER AND ANTIMONY.

Tin.	Copper.	Antimony.	References.
96	4	8	Quoted by Thurston. Ordinary bearings.
90	2	8	" " " Quoted by Hiorns for bearings heavily loaded; used by Russian railroads for car bearings
88·8	3·7	7·4	Quoted by Thurston and Bolley, as Karmarsch metal. Used in France in naval constructions.
87·5	12·5	—	" " Thurston. Karmarsch metal.
87	6	7	" " Hiorns, for bearings heavily loaded.
85	5	10	" " Ledebur and Hiorns as Jacoby metal for light pressure.
83·33	5·55	11·11	Used for car bearings, "Compagnies de l'Est, P. L. M., Ouest," etc.
83	6	11	Quoted by Ledebur. Used by Berlin railroads.

Tin.	Copper.	Anti-mony.	References.
82	6	12	Quoted by Ledebur. Used by Orleans and the Western Austrian railroads.
82	8	10	Bearings for valve rods and eccentric collars, "Compagnie du Nord."
81·25	6·25	12·5	Quoted by Thurston and Bolley.
81	5	14	" " Hiorns, for very hard bearings.
80	10	10	" " Thurston. Used by Swiss railroads.
79	—	21	" " Hiorns.
78·5	10	11·5	" " Thurston. Used by Russian railroads.
76·7	7·8	15·5	" " Ledebur and Thurston as English alloy.
76	7	17	" " Hiorns, for bearings lightly loaded.
75	—	25	" " Thurston and Bolley, as Karmarsch metal
73	9	18	" " Thurston and Hiorns, for light pressure.
72·8	9	18·2	" " Ledebur.
72	2	26	" " Thurston and Bolley.
71·4	21·4	7·2	" " Thurston. Karmarsch metal.
71	5	24	Thurston standard white metal. Used by the P. L. M. Company for packing of valves and eccentric collars.
70 73	9·75	19·5	Quoted by Thurston.
67	22	11	" " Thurston. Used by the Great Western Railway (England).
67	11	22	French state railroads.
33·3	22·2	44·5	Quoted by Hiorns. Dewrance metal for locomotives.
12	4	82	" " " for very hard bearings.

ALLOYS OF COPPER, TIN AND ZINC.

Copper.	Tin.	Zinc.	References.
97·2	—	2·5	Quoted by Bolley.
89	8	3	" " Thurston for locomotive bearings.
89	9	2	" " " Italian railroads.
87	8	5	" " Bolley. Hard alloy.
86	14	—	" " Thurston for locomotive bearings.
86	12	2	" " Ledebur. Bearing alloy.
85·25	12·75	2	" " Thurston.
84	14	2	Used by French State railroads for pieces subjected to alternative friction.
83	15	3	Lafond alloy for heavily loaded bearings.
82	18	—	Quoted by Ledebur and Thurston. Car bearings of the "Compagnie du Nord."
82	10	8	Quoted by Bolley.
82	15	3	Orleans Railroad. Valve-rod bearings.
82	16	2	Quoted by Ledebur for locomotive bearings. Used by French State railroads for pieces subjected to circular friction.
80	18	2	Quoted by Thurston and Bolley. Lafond alloy.
78·7	6·3	15	" " Bolley for friction upon cast iron.
78	20	2	" " " and Thurston for car bearings.

Copper.	Tin.	Zinc.	References.
77·4	15·6	7	Quoted by Haswell. Hard bronze for bearings.
58	28	14	" " Thurston. Margraff alloy.
57	14	29	" " Hiorns for propelling-screw shafts.
56	28	16	" " Thurston. Fenton alloy.
6	14	80	Quoted by Hiorns and Thurston. Fenton alloy for locomotive and car bearings.
5·5	17·5	77	Quoted by Ledebur, for high-speed horizontal shafts.
1·6	98·23	—	Antifriction metal analyzed by Dudley.

MISCELLANEOUS ALLOYS.

Copper.	Tin.	Lead.	Zinc.	Iron.	Antimony.	Phosphorus.	References.
10	—	65	—	—	25	—	Bearings for locomotives and tenders.
74	9·5	7	9·5	—	—	—	Quoted by Thurston and Ledebur. Locomotive bearings.
79	8	8	5	—	—	—	Quoted by Bolley and Ledebur. Bearings for engines.
5	—	—	85	—	10	—	Quoted by Ledebur.
8·3	7·6	3	83·3	—	3·8	—	Quoted by Ledebur as Pierrot metal, Beugnot white bronze, used in France in naval constructions.
5·6	17·5	0·7	76·2	—	—	—	White bronze used for ship engines.
1·6	46	—	52	—	0·4	—	Dunnlevic and Jones metal.
4	19	5	60	—	3	—	Quoted by Ledebur. Babbitt metal.
—	15	25	50	—	—	—	Quoted by Ledebur. Kniess metal.
5	32	60	—	—	3	—	Used by the western railroads (France) for piston-rods and eccentric packings.
4	73	7	—	—	12	Phosph. Copper. 4	Packing for bearings and eccentric collars. Western Railroad (France).
70·20	4·25	14·74	10·20	0·55	—	—	Camelia metal analyzed by Dudley.
4·01	9·91	1·15	85·57	—	—	—	Salge antifriction metal analyzed by Dudley.
75·47	9·72	14·57	—	—	—	—	Carbon bronze analyzed by Dudley.
77·83	9·60	12·40	—	—	—	—	Cornousilles bronze analyzed by Dudley.
92·39	2·37	5·10	—	0·10	—	—	Delta metal analyzed by Dudley.
—	—	83·55	—	—	16·45	—	Magnolia metal analyzed by Dudley.

Copper.	Tin.	Lead.	Zinc.	Iron.	Anti-mony.	Phosph. Copper.	References.
—	—	78·44	0·98	0·65	19·60	—	American antifriction bronze analyzed by Dudley.
59	2·16	0·31	38·40	0·11	—	—	Tobin bronze analyzed by Dudley.
78·50	9·20	15·06	—	—	—	—	Graney bronze analyzed by Dudley.
76·41	10·60	12·52	—	—	—	—	Damar bronze analyzed by Dudley.
90·52	9·58	—	—	—	—	—	Manganese bronze analyzed by Dudley.
81·24	10·98	7·27	—	—	—	0·37	Ajax bronze analyzed by Dudley.
55·73	0·97	—	42·67	0·68	—	Phosphorus. —	Harrington bronze analyzed by Dudley.
—	—	84·33	—	0·61	14·38	—	Bearing metal for cars analyzed by Dudley.
79·17	10·22	9·61	—	—	—	0·94	Phosphor-bronze analyzed by Dudley.
76·80	8	15	—	—	—	0·20	B. metal. Car bearings of the Pennsylvania Railroad.

Composition of the Alloy.	Loss of Weight per sq. cm. after Twenty Minutes.
Pure lead	0·008
20 per cent. antimony	0·180
30 " " "	0·328
40 " " "	0·404
50 " " "	0·588
60 " " "	0·700
Pure antimony	1·160

DISCUSSION.

MR. PAUL KREUZPOINTNER asked whether any experiments had ever been made to determine the amount or ratio of wear of bearing metal of a fine-grained structure and a coarse-grained structure; or, in other words, whether a fine-grained structure offered any decided practical and economic advantages.

MR. CLAMER:—I have no absolute figures to show the rate of wear of a fine-grained alloy as compared with a coarse-grained alloy of the same composition. But in a general way I think it is quite well known that a fine-grained alloy will show a slower rate of wear. Our idea or definition of wear is "the tearing off of small particles from the worn

body," and Dr. Dudley, in a paper read before this Institute some years ago, showed that in consequence of this conception of wear, it must necessarily follow that a metal of fine-grained structure will wear slower, owing to the smaller size of the torn-off grains. His observations were particularly in connection with rails, but undoubtedly the same holds good for bearings.

MR. A. E. OUTERBRIDGE, JR., asked if the author had ever had any experience with the casting of metal in chill molds, and if so, what effect he had noted on the quality of the metals. He also referred to some observations he had made while connected with the Philadelphia Mint regarding the structure of a copper, tin and zinc alloy, used for manufacture of pennies, when cast in sand, and the same metal when cast in a chill.

MR. CLAMER:—Some years ago I had some experience in this connection in casting car bearings, and so far as the structure and physical properties were concerned, viz.: tensile strength and elongation, the chill castings showed a decided improvement, but the difficulty experienced was in obtaining castings free from blow-holes, and to obtain a satisfactory mold which could be easily handled, and the great expense attached to getting up such molds for miscellaneous castings, owing to the great number required.

MR. ROBERT JOB:—I have been very much interested in Mr. Clamer's study of bearing metals, and am glad to note the systematic manner in which his composition has been worked out. Every one concerned in motive power and equipment matters is directly interested in the problem of reduction of hot boxes, and careful attention has been given the subject upon many roads. The composition of the bearing is an important matter, but it is but one of a number of variables, each of which may greatly affect the final outcome in service. Correct foundry practice is a most essential factor, as also are the fitting of the bearing, the lubrication and the quality of packing-waste, as well as the efficiency of the protection of the bearing from dust and cinders. A special study of these matters was begun upon the Reading Railway several years ago, and some account of the

general results appeared in the *Journal* of this Institute in June, 1900. By following out these and other lines of work I am glad to say that a very marked reduction in the number of hot boxes has been effected in the past few years, in spite of material additions to our car and locomotive equipment.

Hot boxes are not by any means the necessary attendant of train service that they sometimes are considered, and careful study of the conditions and causes in any particular case may often effect remarkable changes.

Book Notices.

Galvanic Batteries: Their theory, construction and use; comprising primary, single- and double-fluid cells, secondary and gas batteries. By S. R. Bottone. (With 144 illustrations.) 8vo, pp. xvi + 376. London and New York: Whittaker & Co. 1902.

So far as the reviewer is aware, there is no modern work in English treating of this important branch of applied electricity. The works of Napier, Niaudet and Prescott, very useful in their day, are now more or less antiquated, and a modernized work on the subject by an author of good repute should prove a welcome addition to current electrical literature. W.

The A B C of Photomicrography: A practical handbook for beginners. By W. H. Walmsley, F.R.M.S., etc. 12mo, pp. viii + 155. New York: Tennant & Wood. 1902.

The author endeavors in this work to fill the need for a handbook of instruction in the elementary branches of the art of photomicrography, concerning which there appears to be a dearth of literature. Mr. Walmsley is one of the pioneers in this field and an expert of the highest repute. His book should fill its intended purpose thoroughly well. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 17, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1903

President JOHN BIRKINBINE in the chair.

Present, 56 members and visitors.

Additions to membership since last report, 17.

The election of a member of the Board of Managers to take the place of Mr. James M. Dodge, lately elected Vice-President, was, on motion, postponed until the next stated meeting.

Prof. Lewis M. Haupt read a paper "On the Control of the Floods of the Mississippi River," and by special request supplemented this by a communication "On the Conservation and Increase of the Beach Front at Atlantic City, N. J." Both communications were illustrated with the aid of lantern slides.

The thanks of the meeting were voted to the speaker, and his communications were referred to the Committee on Publications.

The Yawman & Erbe Manufacturing Company, of Philadelphia, through one of its representatives, described and made a demonstration of a Rapid Roller Copying Machine for copying letters. Referred to the Committee on Science and the Arts.

Mr. W. N. Jennings exhibited a number of interesting lantern photographs, including a view over Boston, made from a free balloon by Prof. Samuel A. King, in October, 1860, and one of the alto-reliefs in the Broad Street Station of the Pennsylvania Railroad, made by an exposure of one hour to the incandescent electric light illuminating the Station.

Adjourned.

LOUIS E. LEVY,
Secretary pro tem.

Committee on Science and the Arts.

[*Abstract of proceedings of the stated meetings held May 6 and June 3, 1903.*]

MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2181.) *Enclosed Arc Lamp.*—C. J. Toerring, Philadelphia. Previously reported. On reconsideration, the Edward Longstreth Medal of Merit is awarded to the inventor. [*Sub-Committee.*—L. F. Rondinella, Chairman; T. C. Smith, A. J. Rowland, W. C. L. Eglin, C. C. Heyl, Wm. McDevitt.]

(No. 2230.) *Speed Controller.*—Consolidated Machine Specialty Company, Boston, Mass.

Not susceptible of abstraction without illustrations. The Edward Longstreth Medal of Merit is awarded to the Company. [*Sub-Committee.*—Chas. Day, Chairman; Tinius Olsen, Lucien E. Picolet.]

(No. 2272.) "*Radial-Duplex*" *Gang Cutters.*—Gould & Eberhardt, Newark, N. J. (An advisory report.)

(No. 2273.) *Enclosed Arc Lamp.*—Louis B. Marks, New York. (An advisory report.)

(No. 2274.) *Valve Mechanism.*—E. J. Armstrong, Erie, Pa. (An advisory report.)

(No 2276.) *Improvement in the Art of Butter-Making.*—Chas. M. Taylor, Jr., Philadelphia.

This invention describes an absorptive process for separating the butter-fat from the casein and watery constituents of cream. The report is reserved for publication in full. The award of the John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—S. P. Sadtler, Chairman; F. A. Genth, Edward Woolman, George Malony.]

(No. 2278.) *Speed-Changing Pulley.*—Speed-Changing Pulley Company, Indianapolis, Ind. (An advisory report.)

(No. 2286.) *Improvements in Steam Engines.*—Peter Christian, Johnstown, Pa. (An advisory report.)

The following reports passed first reading:

(No. 2240.) *Heat Gage.*—E. F. Morse, Trumansburg, N. Y.

(No. 2252.) *Enclosed Fuse Protective Devices.*—Joseph Sachs, Hartford, Conn.

(No. 2261.) *Process of Fireproofing Wood.*—Joseph L. Ferrell, Philadelphia.

(No. 2263.) *The Addressograph.*—Addressograph Company, Chicago. Ill.

(No. 2271.) *Brazing Cast-Iron.*—American Brazing Company, Philadelphia.

(No. 2287.) *Spiral Elevator.*—D. E. Condon, San Francisco, Cal.

(No. 2293.) *The School City.*—Wilson L. Gill, New Paltz, N. Y.

W.

[*Abstract of proceedings of the adjourned meeting of June 10th and of the special meeting of June 16th.*]

June 3d, MR. CHAS. E. RONALDSON in the chair.

The following reports were adopted:

(No. 2240.) *Heat Gage.*—Everett F. Morse, Trumansburg, N. Y.

ABSTRACT.—This invention is protected by several letters-patent of the United States, Nos. 696,619 and 696,828, issued to applicant April 1, 1902. The first covers the process, and the second the method of gaging the temperature by heated substances.

The report is reserved for publication in full. The John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—G. H. Clamer, Chairman; John M. Hartman.]

(No. 2252.) *Enclosed Electric Fuses.*—Joseph Sachs, Hartford, Conn.

ABSTRACT.—The fundamental patent covering this invention is numbered 522,252, and dated July 3, 1894. A number of patents have been issued covering details.

The report finds that applicant has greatly improved the art by the introduction of a solvent flux in the interior of the chamber and surrounding the fuse. The function of this flux is to dissolve and remove from the surface of the fuse the coating of oxide which is formed, and which tends to retain the metal of the fuse-wire in the circuit after it is melted, thus preventing an immediate rupture of the circuit.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—C. J. Reed, Chairman; Thomas Spencer, Francis Head.]

(No. 2261.) *Process and Apparatus for Fireproofing Wood.*—Joseph L. Ferrell, Philadelphia.

This report is reserved for publication in full. The Elliott Cresson Medal is awarded to the inventor. [*Sub-Committee.*—Richard L. Humphrey, Samuel P. Sadtler, Wm. McDevitt, A. Raymond Raff.]

(No. 2263.) *The Addressograph.*—The Addressograph Co., Chicago, Ill.

ABSTRACT.—This invention is intended to solve the problem of rapidly addressing, for mailing purposes, circulars, wrappers, etc., for periodical publications, and is a labor-saving device of the highest importance. It is protected by letters-patent of the United States, as follows: No. 558,936, April 28, 1896; No. 579,706, March 30, 1897; and No. 656,442, August 21, 1900, granted to J. S. Duncan, Chicago, Ill.

The report is not adapted for intelligible abstraction without the aid of illustrations. The John Scott Legacy Award is recommended to the inventor. [*Sub-Committee.*—J. Logan Fitts, Chairman; Ernest M. White.]

(No. 2271.) *Brazing Cast-Iron.*—American Brazing Co., Philadelphia.

ABSTRACT.—This process is the invention of Frederick Pich, and is protected by letters-patent of the United States, No. 647,631, of April 17, 1900, and No. 688,030, of December 3, 1901.

The first patent describes a method for brazing or hard-soldering of cast-iron, and the latter a soldering compound or flux for said purpose.

The flux is a mixture of sub-oxide of copper or of other oxides with borax. By the use of this material soldering of cast-iron is readily accomplished at a temperature sufficiently high to melt the solder. A Certificate of Merit is awarded to the Company. [*Sub-Committee.*—G. H. Clamer, Chairman; J. M. Hartman, Thos. P. Conard, Frank Roselle.]

(No. 2286.) *Improvements in Steam Engines.*—Peter Christian, Johnstown, Pa.

(An advisory report.)

(No. 2287.) *Spiral Elevator.*—Daniel E Condon, San Francisco, Cal.

(An advisory report.)

(No 2293.) *The Educational System called "The School City."*—Wilson L. Gill, New Paltz, N. Y.

Reserved for publication in full. The Elliott Cresson Medal is awarded to the inventor. [*Sub-Committee.*—Louis E. Levy, S. P. Sadtler, H. F. Keller.]

W.

Sections.

[*Abstracts of stated meetings.*]

ELECTRICAL SECTION.—*Stated meeting* held Thursday, May 28th, 8 P.M. Mr. Thomas Spencer in the chair. Present, 30 members and visitors.

The meeting was devoted to the reading and discussion of a paper by Mr. Percy H. Thomas, Westinghouse Electric and Manufacturing Company, Pittsburg, on "Static Discharges on Electric Circuits." The paper was fully illustrated with the aid of apparatus and diagrams, and will be published in full in the JOURNAL.

The meeting passed a vote of thanks to the speaker and adjourned.

WM. H. WAHL,
Secretary pro tem.